# A MIDDLE PENNSYLVANIAN FORAMINIFERAL FAUNA FROM DUBOIS COUNTY, INDIANA

*by*
JOSEPH ST. JEAN, JR.

Indiana Department of Conservation
GEOLOGICAL SURVEY
Bulletin No. 10

1957

STATE OF INDIANA
HAROLD W. HANDLEY, GOVERNOR

DEPARTMENT OF CONSERVATION
EDWIN K. MARLIN, DIRECTOR

GEOLOGICAL SURVEY
CHARLES F. DEISS, STATE GEOLOGIST
BLOOMINGTON

BULLETIN NO. 10

# A MIDDLE PENNSYLVANIAN FORAMINIFERAL FAUNA FROM DUBOIS COUNTY, INDIANA

BY
JOSEPH ST. JEAN, JR.

PRINTED BY AUTHORITY OF THE STATE OF INDIANA
BLOOMINGTON, INDIANA

February 1957

For sale by Geological Survey, Indiana Department of Conservation, Bloomington, Indiana
Price $1.75

# SCIENTIFIC AND TECHNICAL STAFF OF THE GEOLOGICAL SURVEY

CHARLES F. DEISS, State Geologist

JOHN B. PATTON, Principal Geologist

BERNICE M. BANFILL, Administrative Assistant to the State Geologist

MARY BETH FOX, Mineral Statistician

*Coal Section*

Charles E. Wier, Geologist and Head
G. K. Guennel, Paleobotanist
S. A. Friedman, Geologist
Henry H. Gray, Geologist
Harold C. Hutchison, Geologist
Richard L. Powell, Geologic Assistant

*Geochemistry Section*

R. K. Leininger, Spectrographer and Head
Maynard E. Coller, Analytical Chemist
Louis V. Miller, Coal Chemist
Robert F. Conley, Spectrographer
E. M. Craig, Laboratory Technician

*Geophysics Section*

Maurice E. Biggs, Geophysicist and Head
Judson Mead, Research Advisor
Robert F. Blakely, Geophysicist
Charles S. Miller, Instrument Maker
Joseph F. Whaley, Geophysicist
Raymond Robinson, Driller
Glen L. Workman, Driller's Assistant
Arthur Wayne Aynes, Geophysics Technician

*Glacial Geology Section*

William J. Wayne, Geologist and Head
William D. Thornbury, Research Advisor
Philip W. Harrison, Geologist

*Industrial Minerals Section*

Duncan J. McGregor, Geologist and Head
Wayne M. Bundy, Petrographer
Seymour S. Greenberg, Petrographer
Haydn H. Murray, Clay Mineralogist
John M. Smith, Geologist
Ned M. Smith, Geologist
Jack A. Sunderman, Geologist
Ross Hickam, Preparator

*Paleontology Section*

Robert H. Shaver, Paleontologist and Head
T. G. Perry, Research Associate

*Petroleum Section*

T. A. Dawson, Geologist and Head
G. L. Carpenter, Geologist
Allan M. Gutstadt, Geologist
Olin R. Holt, Geologist
Andrew J. Hreha, Geologist
Stanley Keller, Geologist
Arthur P. Pinsak, Geologist
Reevan D. Rarick, Geologist
Howard Smith, Geologist
Dan M. Sullivan, Geologist
George Abbott, Draftsman
Phillip W. Cazee, Assistant Sample Curator

*Publications Section*

Gerald S. Woodard, Editor
William H. Moran, Chief Draftsman
Robert E. Judah, Draftsman
Micky P. Love, Draftsman
John E. Peace, Draftsman
George R. Ringer, Photographer

# CONTENTS

| | Page |
|---|---|
| Abstract | 7 |
| Introduction | 7 |
| Local stratigraphy | 8 |
| Acknowledgments | 9 |
| Fossils of the Staunton formation | 9 |
| Physical and biological environment of Staunton fauna | 11 |
| Correlation of Staunton Foraminifera with other middle Pennsylvanian Foraminifera | 13 |
| Orientation of small Foraminifera for thin sectioning | 15 |
| Wall structure of Pennsylvanian small Foraminifera | 17 |
| Phylogeny of the Staunton genera | 19 |
| Systematic descriptions | 22 |
| Family Spirillinidae | 22 |
| Family Endothyridae | 23 |
| Family Nodosinellidae | 41 |
| Family Fusulinidae | 42 |
| Selected bibliography | 54 |
| Glossary | 58 |
| Index | 63 |

# ILLUSTRATIONS

[Plates follow index]

Plate 1. *Hemigordius* and *Endothyra.*

2. *Endothyra, Endothyranella,* and *Bradyina.*

3. *Bradyina, Globivalvulina, Tetrataxis,* and *Polytaxis.*

4. *Polytaxis, Earlandia, Ozawainella, Pseudostaffella,* and *Eoschubertella.*

5. *Eoschubertella, Profusulinella, Fusulina,* and *Wedekindellina.*

Page

Text figure 1. Map of Holland area, Dubois County, Ind., showing collecting locality .......... 8

2. Columnar section of Pennsylvanian rocks of southwestern Dubois County, Ind. .......... 12

3. Phylogeny of the Staunton genera .......... 20

# TABLE

Page

Table 1. Stratigraphic and geographic distribution of 23 species of Staunton Foraminifera and their comparative abundance at Holland, Ind. .......... 14

# A MIDDLE PENNSYLVANIAN FORAMINIFERAL FAUNA FROM DUBOIS COUNTY, INDIANA

BY JOSEPH ST. JEAN, JR.

## ABSTRACT

This report describes 23 species belonging to 14 genera of lower middle Pennsylvanian Foraminifera from a single outcrop in Dubois County, Ind. Three new species of *Endothyra* and one of *Endothyranella* are described. Seven species belong to the family Fusulinidae; the other species are the small Foraminifera. A consideration of the biologic and lithologic constituents of the outcrop indicates that the fauna is cosmopolitan and is from shallow water. The large number of young specimens indicates that the fauna probably was protected from predators and from adverse physical conditions. Most of the specimens are phyloneanic (small simple forms which lack complexities of ornamentation and structure). The Foraminifera correlate especially well with formations of early Des Moines age in Illinois, Texas, and Oklahoma. Species range from lower to upper Pennsylvanian in age.

Thin sections of every species were made to show that in every species the wall is calcareous and in many species is composed of a thin, dense, tectumlike outer layer and a thicker, transversely fibrous or alveolarlike inner layer. The granular appearance which some students of Foraminifera have termed arenaceous is not arenaceous or agglutinated, but is caused by recrystallization of the original wall during the processes of fossilization. Wall structure, phylogeny, and techniques in sectioning small Upper Paleozoic Foraminifera are discussed.

Special attention is given to *Endothyra bowmani* Phillips, the genotype of *Endothyra; Plectogyra* Zeller is placed in synonomy with *Endothyra.*

## INTRODUCTION

Foraminifera from the Pennsylvanian of Indiana are scarce and not well known. No fauna of small Foraminifera has as yet been published from the Indiana-Kentucky-Illinois Basin. An occurrence of "*Fusulina cylindrica* Fisher" was noted by White (1884, p. 116). A foraminiferal fauna from the lower Pennsylvanian, of Spencer County, Ind., was the subject of a Master's thesis by F. P. Schweers, at Indiana University, in 1940, but it has not been published.

A study of the present fauna and similar faunas of other reported Pennsylvanian horizons indicates that they would be of much stratigraphic importance in the Illinois Basin and would be valuable in correlating surface and subsurface formations throughout the midcontinent area. The purpose of this paper is to describe and illustrate the Staunton fauna, with special attention to Pennsylvanian foraminiferal wall structure.

## LOCAL STRATIGRAPHY

A well-preserved fauna of both megascopic and microscopic fossils was discovered by Mr. K. M. Waters in 1950 when he was working on his thesis, A geologic report upon the Holland area, Dubois County, Ind. Mr. Waters' work has not been published. Later, I went to the locality and collected a large quantity of material from which the foraminiferal fauna described in this paper was obtained. The fauna is from a small outcrop of limestone and calcareous shale 1 mile south of Holland and about a quarter of a mile upstream and east of a culvert on a branch of Pokeberry Creek that crosses Indiana Highway 161. The outcrop is in the SE¼NE¼NE¼ sec. 26, T. 3 S., R. 6 W. A similar exposure is in a gully about 100 feet north of the main outcrop (fig. 1).

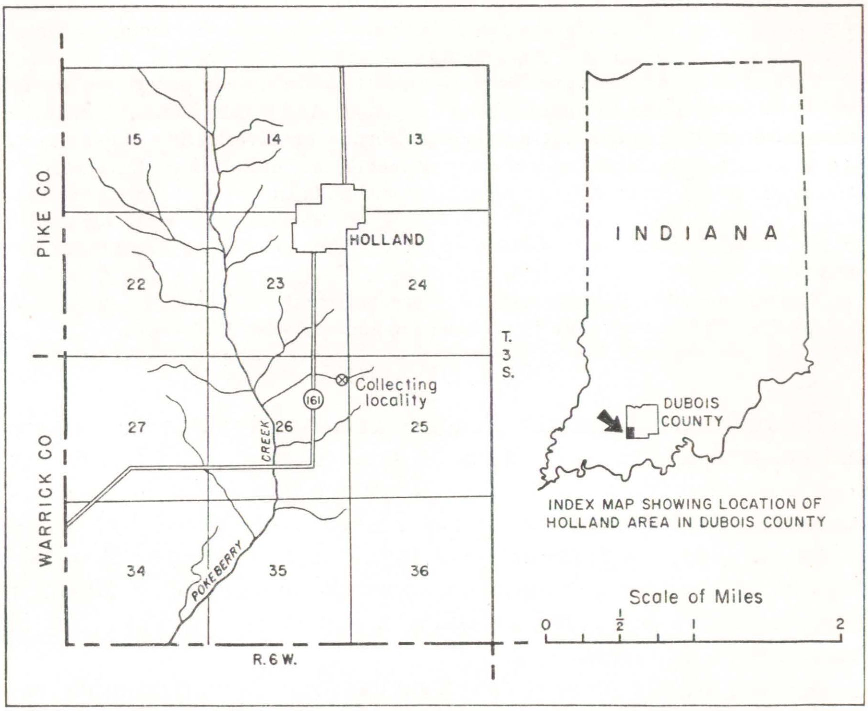



Figure 1.—Map of Holland area, Dubois County, Ind., showing collecting locality.

The limestone is in the basal part of the Staunton formation. It is dense, gray to slate-colored, and fine-grained and has only a few remote calcite crystals large enough to be seen with the unaided eye. On the weathered surface the limestone is characteristically a light brown to earthy color and is dotted with well-preserved and partially weathered out megafossils and Fusulinidae.

The microfauna described in this paper came from the top of a 1-foot section of thin, loosely consolidated calcareous shale at the base of the limestone. This fauna is similar to that in the overlying limestone. There are many fragments of calcareous material in the shale which either may have been derived from the overlying limestone or formed as concretions.

The Staunton fauna is well preserved by infiltration with calcium carbonate, and the finer details of ornamentation and surface features are intact on some of the specimens. The tests of some specimens appear translucent in part, and minute surface pits are clearly discernible.


ACKNOWLEDGMENTS

I am indebted to Mr. K. M. Waters, now with the California Company, who first discovered the fauna in the Holland area, gave permission to describe it, and supplied information concerning the local stratigraphy. Much credit is due Dr. J. J. Galloway, of Indiana University, for his patient and helpful criticism, suggestions, and encouragement. Mr. C. E. Wier, of the Coal Section, Indiana Geological Survey, supplied information concerning the general and local stratigraphy. Mr. G. R. Ringer, photographer with the Indiana Geological Survey, did the photomicrographs of the thin sections.


## FOSSILS OF THE STAUNTON FORMATION

Every phylum of the animal kingdom found as fossils is present in the Staunton formation except the Porifera. The Protozoa are very well represented by Foraminifera, the order with which this paper is concerned. The Coelenterata are represented by many zaphrentid corals, belonging to probably not more than 2 or 3 species. The Annelida are represented entirely by the species *Spirorbis anthracosia* Whitfield and the Echinodermata only by abundant crinoid columnals. All the crinoid stems seem to be of the same kind, even though they range in size from less than 1 mm to more than 9 mm in diameter. They are simple and are smooth on the outside and have a circular, hollow center; the radial grooves are straight and extend from the center to the outer edge. Some echinoid plates are present. The Bryozoa are mostly fenestellid and are abundant, but they are all small in size. There are several specimens of *Prismopora* and *Rhombopora*. The Brachiopoda are not abundant. The genera *Hustedia, Composita,* and *Marginifera* seem to be most characteristic of the brachiopods. A fragment of a spiriferoid brachiopod was found. The Mollusca are represented entirely by internal molds of low-spired gastropods, which resemble the genus *Naticopsis*. The Arthropoda except for the Ostracoda are rare. The Ostracoda are very abundant, however, especially the genera *Amphiscites* and *Bairdia*. A few pygidia of the trilobite genus *Phillipsia* were found. The Vertebrata are represented by moderately abundant conodonts, which are mostly those with bars and sharp denticles.

All specimens described and illustrated are in the type paleontologic collections at Indiana University, Bloomington, Ind.

Since so many small specimens of brachiopods, crinoid stems, fusulines, and bryozoa had been found, I thought at first that the Staunton fauna might be dwarfed. Further investigation showed that the small brachiopods had few growth lines and only beginnings of plications, indications that these brachiopods were young rather than dwarfed specimens. Two gastropods, each about 1 mm in diameter, were found; they consist of only a few whorls and are obviously young specimens. The Foraminifera, corals, bryozoa, worms, ostracodes, most of the brachiopods, and the conodonts are of normal size. One can conclude, therefore, that the forms are young organisms rather than dwarfed. Between 40 and 50 percent of the entire fauna seems to be nepionic or neanic. From 40 to 50 percent is ephebic, and probably less than 5 percent is gerontic. *Endothyra, Fusulina, Ozawainella, Pseudostaffella, Spirorbis,* and *Bairdia* for the most part are phyloneanic (racially young), and *Wedekindellina, Endothyranella,* and *Globivalvulina* are phyloephebic (racially adult). *Tetrataxis, Polytaxis,* and *Bradyina* appear to be phylogerontic (racially old).

In most specimens details of the test may be readily seen, even though specimens of the large inflated *Bradyina* have been distorted and crushed. The smaller forms seem to have thin delicate tests, and a few have chambers that appear almost translucent.

Of the four families of Foraminifera represented in the Staunton fauna, the family Endothyridae is most abundant in number of specimens and in number of species; the family Fusulinidae follows in second place. In number of genera the family Fusulinidae ranks first. The genus *Polytaxis* is represented by more specimens than any other.

Owing to the diverse nature of the fauna, most of the genera anticipated were found. The most noticeable absence was that of *Cribrostomum* and *Climacammina,* which have been found to be abundant in the slightly older Minshall limestone in outcrops about

35 miles south of the Holland area along the bluffs of the Ohio River.

On the whole, the fauna is not pronouncedly specialized. The genus *Bradyina* shows the most specialization and is the only genus that shows much sign of racial senility. The large number of apertures, the irregularity of its asymmetrical coiling, and the large involute chambers, which are easily distorted, bear out the idea of phylogerontism.

Species of the genus *Endothyra* show the most variation. *Endothyra* was the ancestor of many diverse forms, such as *Bradyina, Globivalvulina* to *Tetrataxis,* and the fusulines beginning with *Millerella* and *Pseudostaffella.* The species of Fusulinidae also show much variation.

## PHYSICAL AND BIOLOGICAL ENVIRONMENT OF STAUNTON FAUNA

The Pennsylvanian system in Indiana, as elsewhere, is characterized by horizontal and vertical diversity, which indicates that probably at the time of deposition the water was shallow and the adjacent land was low in relief. The members of the Staunton formation shown in the stratigraphic column (fig. 2) are local; in a distance of 10 to 20 miles the facies changes are so great that many of the members cannot be recognized or are nonexistent. This is true of the foraminiferal limestone and shale.

The limestone in the Staunton formation seems to have been deposited in shallow water, and thick-shelled corals and brachiopods in this limestone indicate that the climate at the time of deposition was temperate to subtropical. The limestone probably was deposited in an embayment, which afforded protection to the small organisms from larger preying ones; this may account for the large number of nepionic and neanic specimens in the Staunton fauna.

This fauna is not provincial, even though it probably lived in protected embayments; it had the ability both to migrate and to endure rapid changes in environment. Most of the species in this fauna are widespread throughout central North America and therefore are cosmopolitan. Only a few species in this fauna, however, appear outside of North America.

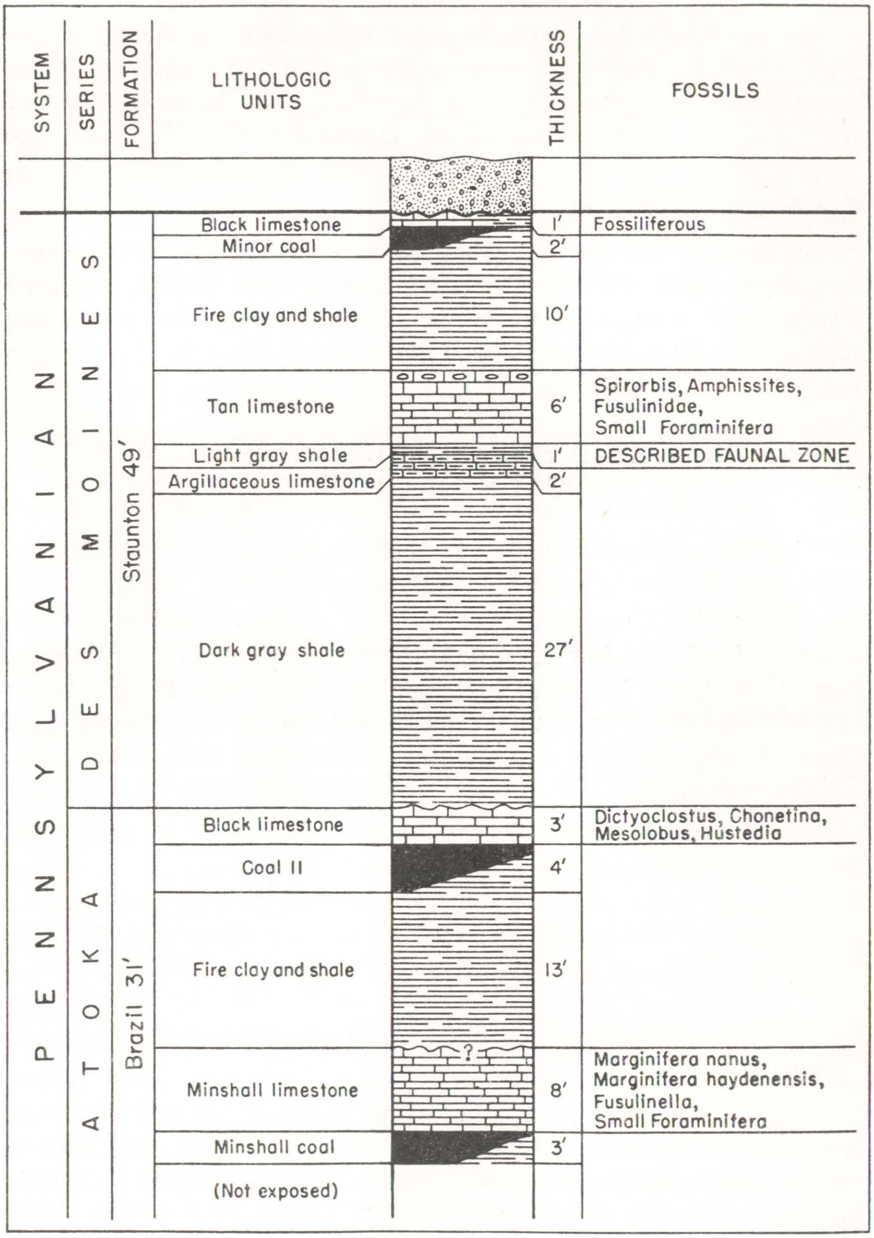



Figure 2.—Columnar section of Pennsylvanian rocks of southwestern Dubois County, Ind.

## CORRELATION OF STAUNTON FORAMINIFERA WITH OTHER MIDDLE PENNSYLVANIAN FORAMINIFERA

The Staunton fauna is similar to other lower and middle Pennsylvanian faunas of the Midwest and Southwest. The best correlation can be made between species of the Staunton fauna and similar species from the Texas-Oklahoma area, since more studies concerning Pennsylvanian small Foraminifera of this area have been published. Because the fauna is from the basal middle Pennsylvanian, about an equal number of species have stratigraphic ranges extending into the lower and middle Pennsylvanian. In Indiana, however, all the species are middle Pennsylvanian in age. (See table 1.)

Most of the species are good index fossils because of their relatively short stratigraphic range. Of these species, *Endothyranella stormi, Hemigordius liratus, Bradyina magna, Polytaxis laheei,* and *Fusulina haworthi* are restricted to the middle Pennsylvanian exclusively. *Wedekindellina euthysepta* and *Fusulina novamexicana,* though present in both the lower and middle Pennsylvanian, do not range below the upper lower or above the lower middle Pennsylvanian. Outside of the Holland area *Eoschubertella mexicana, Pseudostaffella atokaensis,* and *Tetrataxis concava* are found only in the lower Pennsylvanian.

*Earlandia bulbosa, Globivalvulina biserialis, Ozawainella ciscoensis,* and *Tetrataxis corona* range from lower to upper Pennsylvanian. Two of these species are rare, one is common, and one is very abundant in the Staunton formation.

In areas other than that of this study *Endothyra media* is upper Pennsylvanian, *Endothyra whitesidei* is lower and middle Pennsylvanian, *Endothyranella stormi* is middle Pennsylvanian, *Fusulina haworthi* is middle Pennsylvanian, *Ozawainella ciscoensis* ranges from lower to upper Pennsylvanian, and *Polytaxis laheei* is middle Pennsylvanian. All these species are abundant or very abundant in the Staunton formation. Except *Endothyra media,* which has been known previously only from the upper Pennsylvanian, all species represented by the greatest number of specimens have stratigraphic ranges extending from the middle Pennsylvanian, and 4 of the above-mentioned 7 species are restricted to the middle Pennsylvanian.

Table 1.—*Stratigraphic and geographic distribution of 23 species of Staunton Foraminifera and their comparative abundance at Holland, Ind.*

| Species | Indiana | Ohio | Illinois | Michigan | Iowa | Kansas | Oklahoma | Texas | Colorado | New Mexico |
|---|---|---|---|---|---|---|---|---|---|---|
| *Bradyina magna* Roth and Skinner | C | | | | | | | | M | |
| *Earlandia bulbosa* (Cushman and Waters) | R | | | M | | | L | L, U | | |
| *Endothyra kennethi* n. sp. | A | | | | | | | | | |
| *Endothyra media* Waters | A | | | | | | | U | | |
| *Endothyra teres* n. sp. | RC | | | | | | | | | |
| *Endothyra tortilis* n. sp. | A | | | | | | | | | |
| *Endothyra whitesidei* Galloway and Ryniker | AA | | | | | | L | M | | |
| *Endothyranella pugnoidea* n. sp. | C | | | | | | | | | |
| *Endothyranella stormi* (Cushman and Waters) | AA | | | | | | | M | | |
| *Eoschubertella mexicana* Thompson | RC | | | | | | | | | L |
| *Fusulina haworthi* (Beede) | A | | M | | M | M | | M | | |
| *Fusulina novamexicana* Needham | C | | M | | | | | M | | L |
| *Globivalvulina biserialis* Cushman and Waters | RC | | | | | | L | L, U | | |
| *Hemigordius liratus* Cushman and Waters | R | | | | | | | M | | |
| *Ozawainella ciscoensis* (Harlton) | AA | L | | | | | L, M | U | | |
| *Polytaxis laheei* Cushman and Waters | AA | | | | | | M | M | | |
| *Profusulinella fittsi* (Thompson) | C | | | | | | L | | | M |
| *Pseudostaffella atokaensis* (Thompson) | RC | | | | | | L | | | |
| *Tetrataxis biconvexa* n. sp. | R | | | | | | | | | |
| *Tetrataxis concava* Galloway and Ryniker | C | L | | | | | L | | | |
| *Tetrataxis corona* Cushman and Waters | R | | | | | | L | U | U | |
| *Tetrataxis labiata* n. sp. | C | | | | | | | | | |
| *Wedekindellina euthysepta* (Henbest) | AA | | L, M | | L, M | | | | | |

R —rare; 1 to 3 specimens found.
RC—rare to common; 4 to 5 specimens.
C —common; 6 to 8 specimens.
CA—common to abundant; 9 to 10 specimens.
A —abundant; 11 to 15 specimens.
AA—very abundant; more than 15 specimens.

L —lower Pennsylvanian.
M —middle Pennsylvanian.
U —upper Pennsylvanian.

## ORIENTATION OF SMALL FORAMINIFERA FOR THIN SECTIONING

The technique described below was developed as the result of my experiencing considerable difficulty in orienting small Foraminifera in hot balsam for the purpose of preparing thin sections.

The specimen that is to be sectioned is mounted and oriented with gum tragacanth on an ordinary 1 x 3-inch glass slide, as one would mount and orient a specimen on a paper slide. By using a slide that has been frosted on one side one need not transfer the section to a new slide once the section has been made, and one can write detailed labels directly on the glass with india ink. Further, since balsam has an index of refraction near that of glass, the frosted area beneath the cover glass is rendered nearly as transparent by the balsam or cementing medium as if the slide had not been frosted. Dunbar and Henbest (1942, p. 72) have raised objections to using frosted slides because of optical disturbances produced by strain, slight differences of index of refraction of the cements, and fractures in the slide not penetrated by the cement. These conditions are objectionable at high magnifications, but at ordinary magnification the optical disturbances are negligible. Successful photomicrographs are obtainable to at least X100. Nonfrosted slides may be preferable for more precise or detailed work.

The gum tragacanth is soluble in water and becomes quickly viscous as it dries so that the specimen can be worked to the desired orientation with a small 00 brush. The gum tragacanth when dry is not visible. Once the specimen is oriented and glued in position, small chips of Lakeside Thermocement no. 70, manufactured by the Lakeside Chemical Corp., are placed around the Foraminifera. This cement is brittle enough for grinding without being cooked. The slide then is heated until the cement is fused around the specimen to make a support for the fossil while it is being ground. If the cement is heated too long, it becomes more fluid and flattens out; its effectiveness as a support for the specimen is thereby reduced.

A fine-textured carborundum hone is used for grinding the section and is suitable for the entire process. Various grades of abrasives, therefore, are not necessary. In making the section much time usually is spent in locating the proloculus. In many small Foraminifera the proloculus may be seen in transmitted light before it is exposed by grinding. If one wishes to proceed cautiously as he nears the proloculus, one can turn the specimen over and grind it on the reverse side until the proloculus is reached. By warming the slide until the cement is viscous but not highly fluid, one can turn the specimen over. Then the specimen is picked up on the end of a cold needle, such as a dissecting needle. The gum tragacanth will yield as if it had not been used, and thus there is no danger of breaking the specimen by trying to free it from the gum. The best way to pick up the specimen is to slide the needle along the glass until it touches the specimen and then lift the needle gently with a sliding motion in the direction of the specimen until the latter is lifted free of the cement. The slightly viscous cement acts to support the specimen so that this procedure works even when the section is near completion. The needle is given a half twist between the thumb and index finger and gently placed back into the cement. It should be held there for a moment until the specimen comes free. The slide should be left heated for a few moments so that the specimen will tend to settle with its ground side flush against the glass. The slide then is removed from the heat and cooled.

As the proloculus is approached after the specimen has been turned over, one should look at the specimen from time to time in transmitted light. If the slide is turned over and the specimen is again viewed in transmitted light, and if the two views are compared, one can determine how close the proloculus is. When the proloculus is reached, the specimen is turned over for the final time, and the section then is ground to completion. Since the cement is more resistant than the specimen, the rate of grinding can be easily controlled. If the grinding seems to be going rather fast at a crucial point in the process, a slight amount of cement added will slow down the grinding. On the other hand, if it seems to be going rather slowly, the process may be speeded by scraping away some of the cement from around the specimen. Using small quantities of cement at all times proves to be most satisfactory. Further, if the specimen is well impregnated with cement, a reasonable amount of pressure can be applied in the grinding process without danger of ruining the specimen.

Before balsam is added to fix the cover glass to the slide, all excess cement should be scraped from around the specimen. Canadian balsam was used to fasten the cover glass because it does not have to be thoroughly cooked for this purpose and is clear and uncolored even though not cooked to the brittle stage. On the other hand, the Lakeside Thermocement is yellow until it has been cooked. Longer heating increases the chance of bubbles forming under the specimen and perhaps ruining it. The Lakeside cement bubbles more vigorously to begin with than does the balsam.

Results from following the above procedure were so successful that one could make slides of species represented by only one specimen with confidence that the slides would be satisfactory. The external characters of rare species should be illustrated and described before the slides are made.

After the final turning, the specimen can be placed in the desired orientation by gently pushing it around in the hot cement with the needle. Most monocular microscopes produce an inverted image; therefore, if the specimen is oriented upside down on the slide, it will appear properly oriented when viewed through the microscope. In order to study the wall structure properly, one must grind the specimen thin enough for the wall to be clearly translucent in transmitted light. Owing to the small size of some of the specimens, most sections must be ground thinner than the standard 0.03 mm necessary for ordinary petrographic sections. The actual thickness desired may vary slightly from specimen to specimen, depending on the fineness or coarseness of detail of wall features and on the nature of the preservation of the test.

## WALL STRUCTURE OF PENNSYLVANIAN SMALL FORAMINIFERA

A common interpretation of the wall structure of Upper Paleozoic Foraminifera, the Fusulinidae, and the small Foraminifera, is that the wall is arenaceous and contains foreign granules and "irregular fragments of variable size and of various sources" (Cushman, 1948, p. 107), or that the wall is ". . . composed of very tiny granular calcite crystals which are nearly equidimensional and firmly cemented together by clear calcite" (Moore, Laliker, and Fischer, 1952, p. 61).[1] Similar statements on wall structure may be found in other reports. An opposing concept, namely, that the walls are calcareous and transversely fibrous, was introduced earlier by some authorities (Möller, 1878, 1879; Schellwien, 1898). More recent workers also have observed calcareous, transversely fibrous wall structures (White, 1932, p. 6; Galloway, 1933, p. 29, 153, 388; Galloway and Harlton, 1928, p. 24; Galloway and Ry-

[1] The tests of many specimens are composed of granular or crystalline calcite. The calcareous skeleton of any organism, plant or animal, Foraminifera or not, is composed of granular or crystalline calcite, because calcite is not found in nature in any other form. Therefore, the "clear calcite" cement mentioned here may be questioned, since the implication is that the cement exists in some form other than crystalline.

niker, 1930, p. 12, pl. 2, figs. 2, 3 and pl. 4, fig. 14; Dunbar and Henbest, 1942, p. 38; Scott, Zeller, and Zeller, 1947, p. 558, 561, pl. 83, figs. 2, 4, 6; Thompson, 1948, p. 13; Zeller, 1950, p. 4).

Since the fauna from the Staunton formation is remarkably well preserved, thin sections of all the species were made. Almost every specimen that was sectioned showed some indication of transverse fibers similar to the diaphanotheca of the family Fusulinidae and a dense outer layer similar to the tectum. The fibers may range from very fine transverse elements, as in the genera *Endothyra, Endothyranella,* and *Globivalvulina,* to coarse alveolar structures, as in the genus *Bradyina.* In one species, *Endothyranella stormi,* a dense layer was found on both the inside and outside of the wall.

Some specimens have no fibrous wall structure but have test walls composed exclusively of minute calcite crystals of various sizes. Other specimens, however, show a fibrous structure in one part of the test and a granular structure in another part; the fibers grade into the granular material. In these specimens, one may see crystals interspersed in the fibers in the transition zone. One concludes that this phenomenon is the result of recrystallization or alteration of the original wall structure. This conclusion is based upon the following facts: the transitions from fibers to crystals are observed from one part of a test to another part; the crystals of calcite are interspersed among the fibers; the transition zone boundaries are not restricted by individual chamber walls or chamber boundaries; and the occurrence or the lack of a predominantly granular wall seems to have no specific or generic significance. In every specimen sectioned except *Hemigordius liratus* and *Earlandia bulbosa,* the wall showed evidence of being transversely fibrous; there was nothing to indicate an arenaceous or agglutinated condition.

Several specimens were translucent in part, and one specimen of *Endothyranella stormi* was almost as translucent to transmitted light as Recent unaltered hyaline Foraminifera. I am not proposing that the Paleozoic Foraminifera were hyaline, because this term is applied to more recent forms with calcareous, perforate tests, but the translucent chambers strongly suggest that such tests, even with an excess of cement, could not possibly have been arenaceous. The older the fossil, the more altered it is likely to be is a general rule with a few exceptions. Thus, it is not surprising to find specimens of Paleozoic Foraminifera with tests displaying no fibers but only crystalline calcite, since recrystallization if carried far enough will destroy all the finer details of the wall; the smaller the structure, the easier it is obliterated. Gubler (1934, p. 11) and Zeller (1950, p. 4) attribute the dark fibrous lines and tectum to carbonaceous organic material. Carbonaceous organic material probably is not present, as no indication of carbon was noted at magnifications up to X500. Perhaps a better explanation is that the dark lines represent the pattern of original wall structure, the outline of which is brought out by crystal interfaces between recrystallized parts of the original wall material (calcite) and crystallized infiltrated material (calcite). Some of the dark color may be due to small quantities of iron, which gives a yellowish stain to the calcite. In many specimens the crystals of the wall and those of the infiltrated chambers are of marked size difference. No specimen was found with an arenaceous, hyaline porous, or a porcellaneous wall.

For most of the small Foraminifera the details of wall structure were best observed at a magnification of about X200 in fairly strong transmitted light. The thin sections should be thin enough to make the wall translucent at moderately low power (X25 to X75).

## PHYLOGENY OF THE STAUNTON GENERA

Figure 3 shows the phylogeny of the genera found in the Staunton formation. Other genera, such as *Millerella* and *Cribrospira,* have been added to complete the various evolutionary lines as far as shown. The relationship of *Endothyra* to the other small Foraminifera is modified after Galloway (1933, p. 153) to include *Nanicella.* The Fusulinidae are modified after Thompson (1948, p. 22).

Long before Thompson named and described the genus *Millerella* a comparison of the asymmetrical juvenaria and the wall structure of some of the Fusulinidae with *Endothyra* revealed that *Endothyra* was the ancestor of the family. At that time *Nanicella* had not been named and the term *Endothyra* then included the present Devonian *Nanicella.* A comparison of *Nanicella* with its planispiral evolute coil, transversely fibrous wall, and no aperture to *Millerella* suggests that *Nanicella* was the ancestor of both *Millerella* and *Endothyra.*

*Endothyra* was the ancestor of both the small Foraminifera in the Pennsylvanian and the Schubertellinae. *Nanicella,* as suggested above, was the ancestor of the Ozawainellinae. Thompson (1948, p. 22) showed *Eoschubertella* to be derived from *Millerella* and

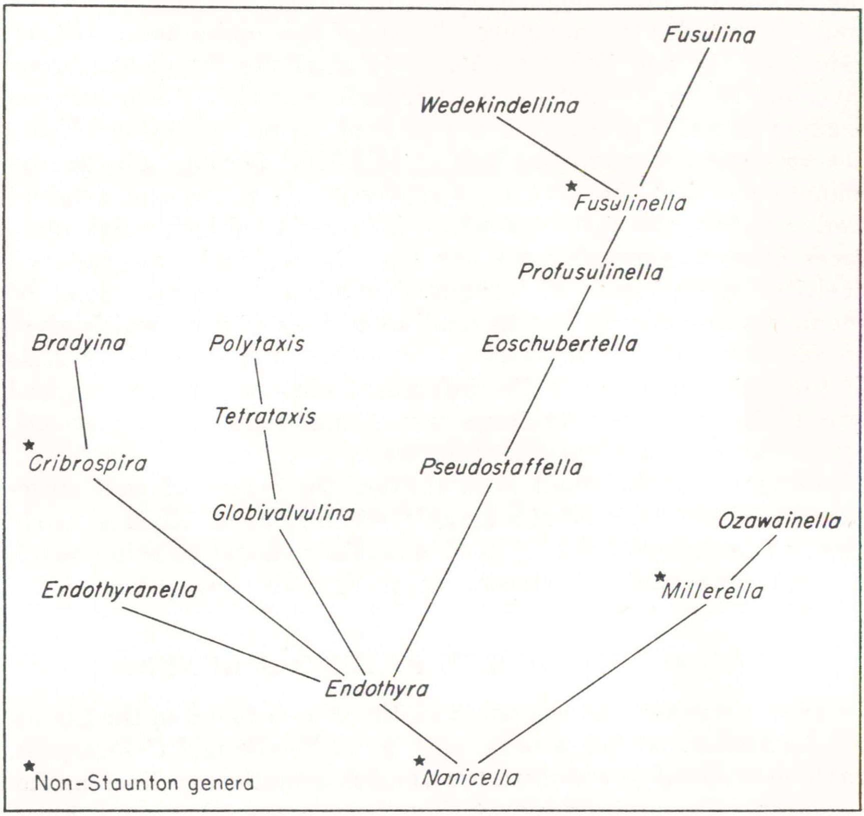



Figure 3.—Phylogeny of the Staunton genera.

*Pseudostaffella* to be derived from *Eoschubertella*. As it seems better to make *Endothyra* the ancestor of those forms with the asymmetrically coiled juvenarium, they are derived from *Endothyra* as shown in figure 3, rather than from *Millerella*, as shown in Thompson (1948, fig. 4). In addition, a more continuous phylogenetic sequence may be shown if *Pseudostaffella* is ancestral to *Eoschubertella*. As a result of reversing the two genera from the way Thompson arranged them, which is not discordant with the occurrence of the two genera in geologic time, the axis becomes progressively longer in younger forms, and fluting becomes progressively more complex. According to Thompson, the axis begins to become elongate in *Eoschubertella*, abruptly shortens in *Pseudostaffella*, and again becomes elongate in *Profusulinella*. This seems unlikely, however, because in still more highly evolved genera the length of the axis continues to lengthen progressively.

Among the small Foraminifera, the most obvious relationship is between *Endothyra* and *Endothyranella.* One can scarcely, if at all, tell the two genera apart if the young coiled stage is separated from the adult stage or if the adult stage has not yet developed. The relationship of *Cribrospira* and *Bradyina* to *Endothyra* is shown by the comparison of the transversely fibrous wall structure, which becomes keriothecalike in *Bradyina,* and the asymmetrical coil, which is well developed in *Bradyina.* *Globivalvulina* illustrates a transition in the development from *Endothyra* to *Tetrataxis,* even though the endothyroid juvenarium in some species of *Tetrataxis* and *Polytaxis* has been reduced and obscured as a result of acceleration. *Globivalvulina biserialis* from the Staunton formation is highly developed and tends to be closer to *Tetrataxis* than to *Endothyra.*

The most common phylogenetic tendency among Foraminifera is to become uncoiled, as is illustrated in the evolution from the closely appressed *Endothyra baileyi* of the middle Mississippian to the loosely appressed Pennsylvanian *Endothyra* and in turn to the uncoiled *Endothyranella.* The tendency to uncoil also is illustrated in a few rare genera of Fusulinidae such as *Codonofusiella* and *Nipponitella.* The tendency to become more tightly coiled is not as common but is obviously dominant among many of the Pennsylvanian Foraminifera. The evolution from *Nanicella* to *Endothyra* and the development of the Fusulinidae as a whole are examples of the tendency to become more tightly coiled.

Except for the famous middle Mississippian *Endothyra baileyi,* little work has been done with Mississippian Foraminifera, but they have been reported from several horizons. Collections from some of the horizons were made by Zeller (1950). At the present time *Millerella* has not been found below the Chester, and *Nanicella* has not been found above the Devonian. *Millerella* very closely resembles *Nanicella;* both are planispirally coiled, are only partially involute, have round backs, and have similar types of walls; neither has an aperture. In view of such striking similarities, it is possible that further information will produce examples to bridge the gap between these two genera. In fact, if one compares forms illustrated from different zones in the Devonian and Mississippian by Zeller (1950, pl. 1, figs. 10, 12-15; pl. 2, figs. 1, 3; pl. 3, figs. 1, 3, 4, 6, 8, 9, 13; pl. 4, figs. 11-14; pl. 5, figs. 11, 12, 15-17), which include both *Nanicella gallowayi* and *Millerella,* a good sequence may be seen through the forms Zeller calls *Endothyra.* More work needs to be done to show both the external and internal characteristics of the various Mississippian forms. Some may actually be *Nanicella* and some *Millerella*. It would be difficult to distinguish *Millerella* from the axial section of *Endothyra* from the St. Louis formation which Zeller illustrated (1950, pl. 4, fig. 12).

In the Staunton fauna, *Endothyranella, Bradyina,* and *Polytaxis* are all end products of evolution. *Endothyra* and the simple Fusulinidae are early forms of a complex phylogeny. The relationship of *Hemigordius* or *Earlandia* to other genera in the fauna is not shown in figure 3 because they are not directly related to the other members of the fauna.

## SYSTEMATIC DESCRIPTIONS

### Family SPIRILLINIDAE Reuss, 1861

### Subfamily SPIRILLININAE Brady, 1884

### Genus HEMIGORDIUS Schubert, 1909

Genotype (monotypic) *Hemigordius schlumbergeri* (Howchin) equals *Cornuspira Schlumbergi* Howchin, 1895, Royal Soc. South Australia Trans. and Proc., v. 19, p. 198, pl. 10, figs. 1-3. Lower Carboniferous, Irwin River, West Australia.

*Hemigordius* Schubert, 1909, Jahrb. K. K. Geol. Reichs. for 1908, Wien, v. 58, p. 381.

Test is a tube coiled glomispirally about proloculus in the young and planispirally and involute in the adult; has alar prolongations beyond the umbo in the type figure; wall calcareous, not arenaceous, finely granular, and transversely fibrous; aperture terminal, crescentic.

### Hemigordius liratus Cushman and Waters

Plate 1, figures 1a, b

*Hemigordius liratus* Cushman and Waters, 1928b, Cushman Lab. Foram. Research Contr., v. 4, pt. 2, p. 44, pl. 5, figs. 11, 12. Middle Pennsylvanian, Palo Pinto County, Tex.

Test unequally biconvex and keeled and consists of a single tube; early part glomospirally coiled and covered by thin layer of calcareous material over umbilical region by involute later whorls; wall calcareous, finely granular, infiltrated, and recrystallized and has minutely pitted surface, which gives granular appearance; aperture small and crescentic, located at end of tube, and distorted in figured specimen. Diameter of test 0.42 mm. Occurrence of species rare.

This specimen has been crushed and the keel broken. The presence of a keel is the most distinctive feature of the species. The early part is coiled at right angles to the plane of the adult whorls. Because of the thin covering over the juvenarium, the inner coils can be seen only with a film of water over the specimen. Only one specimen was found.

A thin section was made of the specimen, but it was so highly recrystallized that one could not satisfactorily make out the details of the wall structure. The specimen was observed in polarized light. All the shell material consisted of minute crystals of calcite.

### Family ENDOTHYRIDAE Rhumbler, 1895

### Subfamily ENDOTHYRINAE Brady, 1884

### Genus ENDOTHYRA Phillips, 1843

Plate 1, figures 2, 3

Genotype (monotypic), *Endothyra bowmani* Phillips, 1846, Geol. and Polytech. Soc., West Riding, Yorkshire, Proc. for 1844-45, v. 2, p. 277, pl. 7, fig. 1. Lower Carboniferous, Yorkshire, England. [Not Brown, 1843, The elements of fossil conchology, p. 17, pl. 6, fig. 2.]—Brady, 1876, Palaeont. Soc. Pub., v. 30, p. 90, pl. 5, figs. 1-3.—Möller, 1878, Acad. Imp. Sci., St. Pétersbourg, Mém., ser. 7, v. 25, p. 89, pl. 12, fig. 2.—Plummer, 1945, Tex. Univ. Bull. 4401, p. 237.—Scott, Zeller, and Zeller, 1947, Jour. Paleontology, v. 21, p. 557, pls. 83, 84.

*Endothyra* and *Plectogyra* Zeller, 1950, Kans. Univ. Paleont. Contr., Protozoa, art. 4, p. 3-4, pls. 3-5.

Test subnautiloid; plane of coiling turns through 30° to 90° during ontogeny; 6 to 11 chambers in outer whorl; whorls few, 3 or 4, partially embracing; wall calcareous, transversely fibrous, and finely alveolar; wall consists of thin, dark outer layer, the tectum, and thicker, fibrous, and alveolar layer, the diaphanotheca; wall not arenaceous, but calcareous wall may be recrystallized, and thus grains of secondary calcite may be formed. Aperture is absent in Mississippian species, but there is a high arch or a slit at the base of the septal face in most Pennsylvanian species. The chambers are connected by foramina (endo thyra), noted by Phillips.

In 1843, Brown published a description and illustration of *Endothyra bowmani* Phillips in a book, The elements of fossil conchology; according to the arrangement of Lamarck with the newly established genera of other authors. His figure was only a median section (see pl. 1, fig. 2), and his description (1843, p. 17) was as follows:

> Genus XI.—ENDOTHYRA—Phillips
> *Generic character.*—Shell involute, discoidal, internally concamerated, the chambers communicating by a large perforation; the septa arranged in stellated order; their emarginations on the inner part of their disk; destitute of any shelly siphuncle. Form of the septal edge unknown. Size, one-fiftieth of an inch.
> *Endothyra Bowmani.* Plate VI. fig. 2. Found in the Mountain limestone of Westmoreland.

This was the first time that *Endothyra* had been described in a publication. Brown clearly indicated in the title of his book that none of the genera described were his own (". . . genera of other authors"), and by placing Phillips' name after *Endothyra* he also clearly indicated that Phillips, not Brown, was the author of the genus. Because at that time *E. bowmani* was the only known species of *Endothyra*, the genus was monotypic, and Phillips was the author of both the genus and the species.

Three years later, in 1846, Phillips published a description and figure of *Endothyra bowmani* (see pl. 1, fig. 3). A comparison of Brown's and Phillips' figures shows many differences. Phillips' illustration shows only 2 whorls, with 6 chambers in the first whorl and 8 in the second; the septa point forward, and the first 2 or 3 chambers are not in the same plane as that of the last whorl. Brown's figure shows 4 whorls, with 10 chambers in the first whorl, 15 in the second, 16 in the third, and 19 in the fourth. The septal or chamber count is that of a fusuline (15 or more to a whorl), not that of Phillips' *Endothyra* (10 or less to a whorl). Brown's figure has more chambers per whorl than any other species of *Endothyra*, and in his example some septa are radial but others point either forward or backward. This proves that the septa are fluted, as in most typical forms of the subfamilies Schubertellinae and Fusulininae. His figure compares well with figures of *Profusulinella* given by Thompson (1948, pl. 27, figs. 3, 7, 10; pl. 28, figs. 26, 27, 30, 31; pl. 29, figs. 5-8). Brown probably had what is now considered to be a *Millerella* or a *Profusulinella*, rather than Phillips' species. Phillips' description (1846, p. 277) is as follows:

> Amongst these fossils I distinguish a beautiful concamerated shell, most probably a Foraminifer, with a large opening in each septum, on the interior edge. Formerly I saw in the possession of Mr. John E. Bowman a specimen of this kind, visible to the naked eye, and named it Endothyra Bowmanni. (See Fig. 1). The volutions are swollen externally between the septa.

Brown erred in assigning his form to *Endothyra*, as judged by present usage, for Phillips' own form must be what Phillips named it and not what Brown mistakenly thought it was. Phillips did not validate Brown's figure or description as representing his own species; in fact, he made no mention of Brown's paper.

Brady (1876, p. 91, pl. 5, figs. 1-4) realized that Phillips' illustration and description were inadequate, but his discussion established what Phillips named as *Endothyra Bowmanni;* he also corrected the spelling of the specific name to *E. bowmani.* Brady collected topotypes and published descriptions and figures of characters of the species. He also obtained similar material from the United States. He considered *Endothyra baileyi* (Hall) as similar to the type species and as characteristic of the genus; this point has been agreed upon almost unanimously for the past three-quarters of a century.

Scott, Zeller, and Zeller (1947) published a paper on *Endothyra* in which they discussed the type of the genus, manner of coiling, and wall structure. They compared Phillips' work with Brown's, discussed Article 21 of the Rules of Zoological Nomenclature in a manner similar to the discussion in this paper, and showed conclusively that Phillips was the author of the genus.

Zeller (1950), 1 of the 3 authors mentioned above, decided that their previous understanding was incorrect and that Brown should be the author of *Endothyra.* Thus he believed that Brown's figure should be the type figure of the genus. Zeller's view is unfortunate for three reasons. First of all, this belief directly violates the Rules of Zoological Nomenclature. Article 21 states:

> The author of a scientific name is that person who first publishes the name in connection with an indication, a definition, or a description, *unless it is clear from the contents of the publication that some other person is responsible for said name and its indication, definition, or description.* (Italics are mine.)

As mentioned above, Brown made it perfectly clear that Phillips was the author. Zeller (1950, p. 2) stated that further consideration of decisions rendered by the International Zoological Commission indicated that in spite of the fact that Brown had attributed the genus to Phillips, Brown should be considered the author. I have failed to find reference to this decision. In fact, Zeller did not cite this decision in his paper.

Secondly, Zeller named a new genus *Plectogyra* to include all the asymmetrically coiled forms; he would apply the name *Endothyra* to the planispiral forms. Thus the name *Endothyra* would apply to a fusulinid. One should compare Zeller's figures of "*Endothyra*" with *Millerella*, *Profusulinella*, and other primitive fusulinids. It is possible that Zeller's "*Endothyra*" is exactly *Millerella*, a possibility suspected by Zeller, for he says (1950, p. 19): "The resemblance of *Millerella* to *Endothyra* cannot be ignored. . . ." Zeller's proposal would change the generic name of all commonly accepted *Endothyra*. The few remaining forms, if any, which are planispiral are by far in the minority. Therefore, the names which have been known and used in the past for well-established forms would no longer be applicable. Zeller has ignored precedent by erecting a new genus. This genus would change the name of all commonly recognized and known *Endothyra*, which have been well established in the literature, and which have been accepted by all authorities and students of micropaleontology since Brady's time.

Finally, confusion concerning *Endothyra* has crept into the literature since the publication of Zeller's paper. For example, Krumbein and Sloss (1951, p. 307) reproduced a phylogenetic chart of Zeller's *Plectogyra*. In the chart Zeller named only one species which was used to establish the genotype, *P. plectogyra;* all the remaining forms are unidentified species. The chart also erroneously shows an *Endothyra* in the Devonian that is not an *Endothyra* at all, but *Nanicella gallowayi* (Thomas) (Thomas, 1931, p. 40; Miller and Carmer, 1933, p. 427; Henbest, 1935, p. 34). Moreover, Zeller's *Plectogyra* (1950, pl. 6, fig. 6a) from the Meramec, listed as sp. C. by Krumbein and Sloss (1951, p. 307), is most likely the well-known *E. baileyi* (Hall), although one cannot be sure because Zeller, like both Phillips and Brown, did not figure the external characters of any of his specimens. As a result of Zeller's work, in one of the recent textbooks on paleontology by Moore, Lalicker, and Fischer (1952, p. 46), *Nanicella gallowayi* from the Devonian was used to represent *Endothyra*. Thus students of paleontology have been given the erroneous idea that *Endothyra* is planispiral and that it characterizes the Devonian.

Zeller has not made a good case in renaming *Endothyra*. Furthermore, the Rules Committee does not need to establish the genotype of *Endothyra*, since it was monotypic at the time the genus was named. The genus *Endothyra*, of course, is variable as any genus must be. If one wishes to make new genera, one conceivably could establish a new genus for those forms in the Pennsylvanian which possess an aperture and which are as involute as are most species in the Mississippian. In establishing a new genus, however, one should attempt to follow the Rules of Zoological Nomenclature, as well as heed precedence, in order to avoid hopeless confusion in the literature.

Wray (1952) also recognized the genus "*Plectogyra*." He maintained that since most forms included under *Endothyra* do not look like Brown's figure, they are not *Endothyra*. There are two errors in this reasoning: (1) Brown's figure is not of the genotype of *Endothyra* because Brown is not the author, as mentioned above; and (2) even though the original description and illustration are incomplete as Phillips' is, we know what Phillips' *Endothyra* was because Brady has collected topotypes from Phillips' locality and has made excellent illustrations and descriptions of *Endothyra*. *Endothyra* is, therefore, what always has been considered *Endothyra*. There are other discrepancies in Wray's article. He stated that there is a tunnel in *Endothyra*, which indicates that his *Endothyra* is *Millerella;* however, none of his figures show the presence of a tunnel. Wray further claimed that there is a tunnel in "*Plectogyra*," but again he failed to illustrate it. He based the distinction between *Endothyra* and "*Plectogyra*" on the twist in the coil, as did Zeller, but every form illustrated by Wray, including what he properly called *Endothyra*, is asymmetrically coiled. His *Endothyra* are planispiral in the outer 2 whorls and asymmetrically coiled in the first 2 whorls. This is a good illustration of the confusion introduced by the genus "Plectogyra." Wray also stated that Zeller had suggested *Endothyra* descended from "*Plectogyra*." On the contrary, Zeller (1950, p. 22 and pl. 6) suggested that "*Plectogyra*" evolved from *Endothyra*, but the *Endothyra* Zeller illustrated from the Devonian is really *Nanicella*.

Zeller (1953) described seven new species of "*Plectogyra*" which, as in the previous studies of the genus, were based exclusively on thin sections. Much emphasis was placed on the "hooks," which appeared to be nothing more than the part of the septal face beneath the aperture. If the aperture was at the base of the septal face there were no "hooks"; if it was high toward the center of the septal face the "hooks" were prominent, as shown in sections of *Endothyra* from the Staunton formation. (See plate 1, figure 7, and plate 2, figures 2a, b.) Thus "*Plectogyra*" seems to resemble the genus *Paraendothyra* described by Chernysheva (1940).

Recently Henbest (1953) discussed the type of *Endothyra* and recognized Phillips' figure to be the type of the genus as interpreted by Brady for reasons similar to those stated above. He has petitioned the International Commission on Zoological Nomenclature to validate *Endothyra* Phillips, 1846, as emended by Brady, and to suppress *Endothyra* Brown, 1843.

One point of interest is that the characteristics of "*Plectogyra*" are based exclusively on thin sections. No one as yet has illustrated or described the external characteristics of "*Plectogyra*." I can make no generic distinction between "*Plectogyra*" and a thin section of any *Endothyra*. However, authors describing "*Plectogyra*" point out the weakness in either Phillips' or Brown's illustrations and descriptions for this very reason. Zeller (1950) illustrated several species but named only one; Wray (1952) illustrated several species but did not name any of them. "*Plectogyra*" probably cannot be distinguished from *Endothyra* by the exterior; therefore, if these Foraminifera are used for stratigraphic work, as in the correlation of well samples, making sections of them probably will not be feasible. The unpracticality of "*Plectogyra*" is one other argument for not using the genus.

Zeller (1950) and Wray (1952) referred to "*Plectogyra*" as endothyroid. Zeller (1953) seemed to use the terms endothyroid and plectogyroid interchangeably. If they used endothyroid to mean the twist in the plane of coil, they are correct (see glossary, p. 58), but at the same time they are implying that there is a confusion of names, since they claimed *Endothyra* is planispiral. If they used endothyroid to mean some other characteristic, then it is difficult to say just what is meant, and the term endothyroid would be reduced to ambiguity. Although this criticism may seem hypercritical, I use it to point out that the people who have named and assigned species to "*Plectogyra*" are not clear in their usage of the name or of the adjective derived from the name; they themselves confuse "*Plectogyra*" with *Endothyra*.

The term *Endothyra* should refer to the genus which was described by Phillips and which was interpreted by Brady (1876) and accepted from that time until the publication of Zeller's paper. Surely no good purpose would be served changing the name *Endothyra* from a genus that is well understood to a genus whose characteristics are scarcely understood at all.

Chernysheva (1940) described a new genus, *Paraendothyra*, which was distinguished primarily by the position of the aperture in the middle of the septal face and the presence of low, geniculate septa which are the "spines" or "horns" referred to in "*Plectogyra*." This genus also may prove to be a synonym of *Endothyra*, but it is left here as a distinct genus until further studies are made. The type figures of the genotype, *Paraendothyra nalivkini* Chernysheva, are shown to be very deeply umbilicate; this may be another distinguishing characteristic. There is no characteristic noted, however, that could be used to distinguish this genus from "*Plectogyra*." In fact, the thin section of *Paraendothyra* designated as the holotype shows the asymmetrical coil and spines of "*Plectogyra*." If *Paraendothyra* is found to be a valid genus, some "*Plectogyra*" may be synonomous with *Paraendothyra*, depending upon what the external characteristics are. The name *Paraendothyra* would have precedence.

Species of the genus ENDOTHYRA from the lower Staunton formation

1a. Aperture a low arch
- 2a. Last whorl asymmetrical .......... *Endothyra tortilis* n. sp., page 27
- 2b. Last whorl nearly planispiral ...... *Endothyra kennethi* n. sp., page 28

1b. Aperture a high arch
- 2c. Periphery smooth; sutures flush, radial ...................... *Endothyra teres* n. sp., page 29
- 2d. Periphery lobulate; sutures depressed, curved
  - 3a. Sutures moderately curved..... *Endothyra media* Waters, page 30
  - 3b. Sutures strongly curved....... *Endothyra whitesidei* Galloway and Ryniker, page 30

### Endothyra tortilis n. sp.

Plate 1, figures 4a-c, 5

Test asymmetrical and thick, with lobulate periphery and broadly rounded back; ovate in side view and strongly twisted; seven moderately inflated chambers in outer whorl, only part of penultimate whorl exposed on dorsal side, and ventral side involute to umbilicus; sutures moderately depressed and curved and oblique to radius of test; wall calcareous and translucent; surface smooth, minutely pitted, and shows no evidence of being arenaceous; aperture a narrow slit at base of septal face; aperture has small upper lip. Longest diameter 0.30 to 0.50 mm; shortest diameter 0.27 to 0.48 mm; thickness 0.13 to 0.25 mm.

A median section shows that this species consists of 2½ whorls (pl. 1, fig. 5). The plane of coiling in the first whorl is perpendicular to the plane of coiling in the last. The plane of coiling in the second whorl is of necessity intermediate between the first and last. The proloculus has an outside diameter of 0.039 mm and a wall thickness of 0.006 mm. The first whorl has a diameter of 0.113 mm;

the second has a diameter of 0.222 mm. The sectioned specimen has an outside diameter of 0.317 mm. The number of chambers in the first and second whorls cannot be seen because of the perpendicular plane of coiling. There are eight chambers in the outer whorl. The septa are slightly curved; the last two extend only part way to the next inner whorl. The outer whorl has a height of 0.083 mm. The aperture is clearly seen at the base of the septal face. Occurrence of species is abundant.

The wall is characteristically thick and transversely fibrous and shows both tectum and diaphanotheca. The specimen is especially interesting when it is magnified about X200 because one can see the transition from the fibrous wall structure of the unaltered part of the test to the granular appearance of the altered part that is caused by the recrystallization of the calcite in the original wall. The recrystallization tends to destroy the original structure.

The species is characterized by: (1) the great amount of twist in the penultimate coil (the last whorl tends to become planispiral), (2) the narrow crescentic aperture, which has a lip, and (3) the lobulate periphery.

The species most closely resembles a young form, *Endothyra excentralis* Cooper (1947, pl. 20, figs. 19-21), from the upper Chester Kinkaid formation of Illinois. It differs, however, in having a larger ratio of length to thickness and in possessing an aperture that extends across most of the septal face. *E. tortilis* also has a well-developed lip. As the sutures are more depressed than in *E. excentralis*, they give the periphery of *E. tortilis* a lobulate outline.

*Endothyra tortilis* is named for the large amount of twist in the plane of coiling.

### Endothyra kennethi n. sp.

Plate 1, figures 6a-c, 7, 8a-c

Test ovate and thick; seven chambers in the outer whorl; back broad; last whorl involute ventrally to umbilicus and only partially involute dorsally; chambers inflated; sutures strongly depressed; wall calcareous and transversely fibrous; surface smooth and minutely pitted; aperture crescent-shaped at base of septal face and has thin upper lip. Longest diameter 0.43 mm; shortest diameter 0.37 mm; thickness 0.32 mm.

Three whorls are visible in the median section (pl. 1, fig. 7); the first whorl is coiled in a plane perpendicular to the plane of coiling of the outer whorl, as in *E. tortilis*, but the outer whorl is coiled more nearly in a uniform plane. The proloculus has an outside diameter of 0.048 mm and a wall thickness of 0.016 mm. The first whorl has a diameter of 0.113 mm, the second a diameter of 0.235 mm, and the third a diameter of 0.506 mm. There are 6 chambers in the second whorl and 7 chambers in the outer whorl. The septa, as seen in section, are slightly curved and extend about three-quarters of the distance to the next inner whorl throughout all the outer coil. The second whorl has a height of 0.087 mm, and the outer whorl has a height of 0.170 mm. The aperture may be seen in the thin section. The incomplete septa in the outer whorl probably represent the aperture at the base of each former septal face. Occurrence of species is abundant.

The wall is thin and transversely fibrous and shows both the tectum and diaphanothecalike structures. The appearance under the microscope is much like that of Möller's figures of *Endothyra* (1878, pl. 12, fig. 2). Recrystallization has obscured the structure of the wall of the inner whorls, but it has not progressed to such a high degree in the outer whorl. Calcite crystals can be seen among the fibers of the wall. The very thin tectum is best observed at the juncture of two chambers in the outer whorl.

The specimens are characterized by the broad back, especially well developed in the thick terminal chambers, and by the moderate twist in the plane of coiling. The involution of the chambers on the ventral side causes the terminal chamber to appear tilted in the apertural view.

*Endothyra kennethi* differs from *E. tortilis* in the smaller amount of twist in the penultimate and outer whorls, the broader back, the more depressed sutures, more inflated chambers, and in the less-pronounced lip. There is less twist in the plane of coiling. In the median section the wall is thinner in *E. kennethi*, and there is one more whorl than in *E. tortilis*.

The species is named for Mr. Kenneth M. Waters who discovered the fauna.

**Endothyra teres n. sp.**

Plate 1, figures 9a-c, 10

Test subnautiloid, slightly asymmetrical, and biumbilicate; periphery nearly smooth; chambers not distinct; about eight chambers in outer whorl; outer whorl embraces about one-half of the younger part ventrally and about three-quarters of the younger part dorsally; sutures not depressed; wall calcareous, translucent, and very finely transversely fibrous (pl. 1, fig. 10); aperture a high arch extending from base of septal face. Longest diameter 0.24 to 0.38 mm; shortest diameter 0.18 to 0.32 mm; thickness 0.12 to 0.19 mm.

Three whorls are visible in a median section (pl. 1, fig. 10). Only the juvenarium shows any sign of twisting. The second and third whorls are planispiral, and the outer whorl is nearly circular in outline. The proloculus has an outside diameter of 0.037 mm and a wall thickness of 0.011 mm. The first whorl has a diameter of 0.039 mm, the second a diameter of 0.090 mm, and the third a diameter of 0.150 mm. The number of chambers in the first whorl cannot be seen; 5 chambers are in the second whorl, and 7 are in the outer whorl. The septa are straight, oblique to the radius; the last three extend only part way to the next inner whorl. The second whorl has a height of 0.026 mm, and the third whorl has a height of 0.030 mm. The aperture was distinguished in thin section, but unfortunately the septal face was destroyed before the section was completed. Occurrence of species is rare to common.

The wall appears granular, owing to recrystallization, but transverse fibers and a dense outer layer can be distinguished in the outer wall above the third, fourth, and fifth chambers.

The species is characterized by its smooth surface, which suggests the name *teres*, and by nondepressed sutures and high arched aperture. The sutures are not as curved as those of the other species in the fauna.

*Endothyra teres* most closely resembles *Endothyra ovata* Waters (1928, pl. 42, figs. 6a, b), but it differs in having a smoother periphery, less obvious suture lines, and a more rectangular outline in edge view. It also is about one-half the size of *E. ovata*.

**Endothyra media Waters**

Plate 1, figures 11a-c, 12

*Endothyra media* Waters, 1928, Jour. Paleontology, v. 1, p. 273, pl. 42, figs. 11, 12. Upper Pennsylvanian, Brownwood, Tex.—? Cushman and Waters, 1930, Tex. Univ. Bull. 3019, p. 47, pl. 3, fig. 17. Upper Pennsylvanian, north-central Texas.

Test asymmetrical; back evenly rounded; periphery slightly lobulate and umbilicate on both sides; more of spire shows on dorsal side; nine chambers in outer whorl; sutures slightly depressed and slightly oblique; wall calcareous and translucent; aperture a small, high arch extending upward from base of septal face, and there are indications of a thin lip. Longest diameter 0.24 to 0.36 mm; shortest diameter 0.18 to 0.30 mm; thickness 0.08 to 0.12 mm.

In median section (pl. 1, fig. 12) three complete whorls may be distinguished. The first whorl is coiled in a plane slightly less than 90° to the plane of coil of the outer whorl. The twist in the coil is nevertheless rapid. The proloculus has an outside diameter of 0.044 mm and a wall thickness of 0.011 mm. The first whorl has a diameter of 0.074 mm, the second a diameter of 0.131 mm, and the third a diameter of 0.209 mm. One can see evidence of at least three chambers in the first whorl. The chamber count in this whorl is not accurate because of the nearly perpendicular plane of coiling. Four chambers can be distinguished definitely in the second whorl, and probably 1 or 2 more are obscured by the twist of the coil. Six chambers are in the third or outer whorl. The septa are curved. The last three septa extend only part way to the next inner whorl. The first whorl has a height of 0.022 mm, the second 0.026 mm, and the third 0.070 mm. The aperture is represented by the opening at the base of the septal face, where the last septum does not extend to the bottom of the chamber in the thin section. Occurrence of species is abundant.

One can see transverse fibers in the outer wall of the second and third chambers from the outer end, but the structure of the wall of the first two whorls is too fine to show granules. The outer part of the wall in many places is darker and denser than the inner part; it is definitely crystalline, however, and suggests the remnants of the original tectumlike structure.

The species is characterized by its nearly circular outline and by its thinness. It differs from *E. ovata* Waters in being less involute and thinner. The specimens from Indiana have a high arched aperture instead of a thin crescent and are less than one-half the size of the Texas holotype, as given by Waters. It differs from *E. whitesidei* Galloway and Ryniker (1930, pl. 2, figs. 4a-c) in being slightly less symmetrical in the last whorl, in being only about one-half the size, and in having sutures that are less curved. The species might well be a young *E. whitesidei*.

**Endothyra whitesidei Galloway and Ryniker**

Plate 2, figures 1a-c, 2a, b

*Endothyra whitesidei* Galloway and Ryniker, 1930, Okla. Geol. Survey Circ. 21, p. 12, pl. 2, figs. 4a-c. Lower Pennsylvanian, Latimer County, Okla.—Plummer, 1930, Tex. Univ. Bull. 3091, p. 16, pl. 1, figs. 7-8. Middle Pennsylvanian, Bridgeport, Tex.—Plummer, 1945, Tex. Univ. Bull. 4401, p. 241, figs. 2a, b. Middle Pennsylvanian, San Saba and Landon, Tex.

Test subnautiloid, biumbilicate, round, and nearly symmetrical; each whorl embraces about one-third of next inner whorl; periphery lobulate; back narrowly rounded; 7 to 8, rarely 9 or 10, inflated chambers in outer whorl; sutures depressed, oblique, and strongly curved; wall calcareous, translucent, and transversely fibrous as seen in thin section; surface minutely pitted; aperture a high arch extending up from base of septal face and without a lip. Longest diameter 0.38 mm to 0.68 mm; shortest diameter 0.30 mm to 0.58 mm; thickness 0.15 mm to 0.27 mm.

In thin section (pl. 2, figs. 2a, b) this widespread species from the lower middle Pennsylvanian beautifully illustrates the manner of coiling and fibrous wall structure typical of *Endothyra.* The test consists of 4 whorls; the plane of coiling in the first 2 whorls is at right angles to the plane of coiling of the last 2. The proloculus has an outside diameter of 0.033 mm and a wall thickness of 0.008 mm. The first whorl has a diameter of 0.071 mm, and the plane of coiling is perpendicular to the plane of the last whorl. The second whorl has a diameter of 0.126 mm; the plane of coiling approaches, but is not quite perpendicular to, the plane of coiling of the outer whorl. The third whorl has a diameter of 0.237 mm. The latter measurement was taken in the direction of maximum diameter because the whorl is elliptical. The plane of coiling is twisted but is nearly parallel to that of the outer whorl. There are 8 septa which are slightly curved, and the last 4 extend only part way to the next inner whorl. The outer whorl has a height of 0.429 mm and contains 9 curved septa. The aperture which seems to be most typical of Pennsylvanian *Endothyra* is clearly visible at the base of the septal face. Occurrence of species is very abundant.

The sectioned specimen (pl. 2, figs. 2a, b) shows clearly the transversely fibrous and alveolar wall structure typical of the family Endothyridae. There are 10 alveoli in 0.047 mm in the outer whorl. The dense, granular, tectumlike structure is much finer and more distinct than it is in *Bradyina;* it enables the line of juncture between two chambers to be seen clearly. At the base of each new chamber the material of the wall is slightly thickened.

The species is characterized by the nautiloid nature of the outer whorl, but the juvenarium is strongly endothyroid. It also is characterized by 7 to 8 chambers in the outer whorl and by the depressed, oblique, strongly curved sutures. The curvature of the sutures, together with the nautiloid adult coil, serves to distinguish the species.

### Genus ENDOTHYRANELLA Galloway and Harlton, 1930

Genoholotype *Endothyranella powersi* (Harlton) equals *Ammobaculites powersi* Harlton, 1927, Jour. Paleontology, v. 1, p. 21, pl. 3, figs. 3a-e. Lower Pennsylvanian, Love County, Okla.

*Endothyranella* Galloway and Harlton, 1930, in Galloway and Ryniker, Okla. Geol. Survey Circ. 21, p. 13; 1930, Jour. Paleontology, v. 4, p. 24.

Test biformed; whorls partly embrace in young stage but become uncoiled and straight in adult; wall calcareous and transversely fibrous; aperture terminal and round. The coiled part may be broken from the uncoiled part, and thus this species may be confused with *Endothyra.* All the juvenaria have the typically twisted endothyroid coil, but some species may be planispiral in the outer whorl. Neanic specimens are said to be in the ancestral or endothyroid stage. It is significant that the juvenaria of all species of *Endothyra* and *Endothyranella* in the fauna are coiled at about 90° to the plane of coiling of the adult whorl.

### Endothyranella pugnoidea n. sp.

Plate 2, figures 3a-c, 4a-c, 5

*Endothyranella minuta* Galloway and Ryniker [not Waters], 1930, Okla. Geol. Survey Circ. 21, p. 14, pl. 2, figs. 5a-c, 6a-c. Lower Pennsylvanian, Latimer County, Okla.

Test asymmetrically coiled in early stage and uncoiled in adult stage; outer whorl partly embracing, nearly to umbilicus on one side and only slightly embracing on other side; twist either dextral or sinistral; side of greatest involution may appear pseudobiserial; outline of young stage elliptical; long axis of ellipse ranges from parallel to angle perpendicular to direction of elongation of adult part of test; aperture simple, round, and terminal. Diameter of endothyroid early stage 0.23 mm, length of 4 uncoiled adult chambers 0.31 mm, and diameter of terminal chamber 0.14 mm.

A median section (pl. 2, fig. 5) shows that the early stage consists of three whorls, as in most *Endothyra*, and that the plane of coiling twists through nearly 90°, as in many *Endothyra*. The first whorl is coiled slightly less than 90° to the plane of coiling of the outer whorl. The proloculus is tiny, measuring only 0.017 mm in outside diameter, and has a wall thickness of 0.002 mm. The first whorl has a diameter of 0.057 mm, the second a diameter of 0.100 mm, and the third 0.200 mm. Each whorl has a diameter nearly double the diameter of the next whorl. The number of chambers in the first and second whorls cannot be determined from the median section because of the twisted coil; 7 chambers are in the third whorl, and 5 chambers are in the adult part of the test. The septa are straight and oblique to the radius. The last septum of the coiled stage extends only part way to the next inner whorl. The sepum of the first uniserial chamber is curved and extends about one-third of the distance to the coiled part; the septum then is built up from the coiled part. In three dimensions the terminal wall is built up on all sides and a central, round apertural opening is left. The wall thickens considerably around the opening. The wall of each succeeding uniserial chamber is outside of the thickened area of the preceding chamber wall. The thickened area becomes proportionally larger in each additional chamber. The aperture in the young stage is a slit at the base of the septal face, as in *Endothyra;* in the uniserial part it is at the center of the septal face, as mentioned above. The aperture is 0.017 mm in diameter in the first adult chamber, 0.019 mm in the second, 0.022 mm in the third, 0.023 mm in the fourth, and 0.043 mm in the fifth. A comparison of these figures strongly suggests that the aperture is partly closed (to about one-half the original diameter) by deposition of secondary material after the addition of a new chamber. The idea of secondary deposition after the addition of a new chamber is further supported by the fact that, although thickening around the aperture of the terminal septum is present, the thickening is not proportionally as great as it is around the preceding adult apertures. Occurrence of species is common.

The wall has been recrystallized to some extent, but one can see remnants of the transverse fibers and a dense outer layer, especially in the thicker walls of the adult part of the test.

The specimens are characterized by the high angle of twist in the coil of the endothyroid part of the test, by the elliptical juvenarium, and by the compressed vertical diameter of all but the terminal chamber of the uniserial part of the test.

The oval outline of the neanic stage differs from that of *E. minuta* (Waters) (1927, pl. 22, fig. 3) in having more compressed chambers. It is difficult to see how the young stage could be distinguished from *Endothyra*. Galloway and Harlton (Galloway and Ryniker, 1930, p. 13) made a distinction based upon the high arched or round aperture in the young *Endothyranella*, but apparently this does not always hold true, as is shown in the median section of *E. pugnoidea*. The aperture of the endothyroid stage appears to be a low arch at the base of the septal face. Straight oblique sutures and minute size may suggest *Endothyranella*, but there are *Endothyra* with these characteristics, for example, *E. media*. Further investigation may reveal some diagnostic characteristic of the neanic stage.

**Endothyranella stormi (Cushman and Waters)**

Plate 2, figures 6a-c, 7

*Ammobaculites stormi* Cushman and Waters, 1928b, Cushman Lab. Foram. Research Contr., v. 4, pt. 2, p. 41, pl. 5, figs. 3, 4. Middle Pennsylvanian, Palo Pinto County, Tex.

Test consists of small coiled endothyroid part and long uniserial part; endothyroid part involute; chambers embrace to umbilicus on one side, and inner whorls seen on the other; 6 or 7 chambers in outer whorl and as many as 7 chambers in uniserial part; wall calcareous and transversely fibrous; surface smooth and minutely pitted; aperture a simple, round, terminal opening. Diameter of neanic stage about 0.25 mm; length of 7 chambers in uniserial part 0.91 mm; diameter of terminal chamber 0.23 mm.

Three complete whorls can be seen in the neanic stage of the specimen cut for a median section (pl. 2, fig. 7). The plane of coiling in the first whorl is at 90° to the plane of coiling of the last. The proloculus has an outside diameter of 0.028 mm and a wall thickness of 0.004 mm. The first whorl has a diameter of 0.057 mm, the second 0.072 mm, and the third 0.136 mm. The number of chambers in the first whorl cannot be determined in a median section. There are more than 4 chambers in the second whorl and 7 chambers in the outer whorl. Five chambers are in the uniserial part of the sectioned specimen. The first whorl has a height of 0.019 mm, the second 0.026 mm, and the third 0.052 mm. All septa are slightly curved; the last five of the endothyroid part of the test extend only part of the distance to the next inner whorl, probably representing former slitlike apertures at the base of the septal faces in the various stages of development. The uniserial part is added in the same manner as it is in *Endothyranella pugnoidea*. The aperture becomes terminal and round, and a definite thickening of the wall around the opening is present. In addition, the new chambers are added outside of the thickened area. The opening of the first chamber in the uniserial series has a diameter of 0.017 mm, the second 0.019 mm, the third 0.019 mm, the fourth 0.028 mm, and the fifth 0.026 mm. Occurrence of species is very abundant.

The wall is transversely fibrous, as in other endothyroid Foraminifera. There is a dense outer layer. The sectioned specimen is unusual in that it also has a dense inner layer, which suggests an inner tectorium. The inner tectorium is best observed in the adult part of the test. The specimen is well preserved and has only a moderate to slight degree of recrystallization of the wall. The wall structures, as well as some fine alveoli, are clearly discernible. Some specimens show a remarkable lack of alteration of the test wall in preservation. Most of the chambers in one specimen pass transmitted light nearly as well as more recent examples of hyaline tests. The walls are unquestionably fibrous and are not hyaline in the sense in which the term has been applied, that is, to forms with calcareous perforate tests. The significance of the translucent test is that the specimen could not possibly be arenaceous. The translucent test further suggests that fibrous forms in general are not arenaceous. The subject is discussed in detail under "Wall structure" in the introductory part of this report.

The species is characterized by the involute, symmetrical outer whorl of the small early stage. *E. stormi* in the early stage is larger and seems to have fewer chambers than *E. minuta* (Waters) (1927, pl. 22, fig. 3). The endothyroid stage of *E. stormi* is circular as distinguished from the elliptical endothyroid stage of *E. pugnoidea.*

### Genus BRADYINA Möller, 1878

Genotype [designated by Cushman, 1927], *Bradyina nautiliformis* Möller, 1878, Acad. Imp. Sci., St. Pétersbourg, Mém., ser. 7, v. 25, p. 78, pl. 3, fig. 4; pl. 10, fig. 3. Pennsylvanian Archangel, Russia.—Cushman, 1927, Cushman Lab. Foram. Research Contr., v. 3, p. 189.

*Glyphostomella* Cushman and Waters, 1928b, Cushman Lab. Foram. Research Contr., v. 4, pt. 2, p. 53-54, pl. 6, figs. 11-13; pl. 7, fig. 1.

Test endothyroid in early stage and planispiral in adult; test involute to umbilicus; chambers broadly rounded, lobulate, and 3 to 7 to a whorl; wall calcareous and has finely porous tectum and coarsely alveolar keriotheca; no indication of wall being arenaceous; apertures a row of slit or round openings extending around base of last chambers; one or more than one irregular row of apertures also may be near top of septal face.

### Bradyina magna Roth and Skinner

Plate 2, figures 8a-c, 9a-c; plate 3, figures 1a, b, 2

*Bradyina magna* Roth and Skinner, 1930, Jour. Paleontology, v. 4, p. 336, pl. 29, figs. 1-4. Middle Pennsylvanian, Eagle County, Colo.

Test large, subglobular; five chambers in outer whorl; back broadly rounded; sutures nearly flush, and there is a row of large, narrow, slitlike pores parallel to suture lines; wall calcareous and has thin, porous tectum and coarsely alveolar keriotheca; aperture an arched row of slitlike pores on septal face; additional slit pores scattered irregularly over septal face. Longest diameter 1.12 to 1.40 mm; shortest diameter 0.94 to 1.00 mm; thickness 0.85 to 0.94 mm.

In both median and axial section the endothyroid juvenarium is seen distinctly; the plane of coiling turns through about 90° per whorl.

There are four whorls in the median section (pl. 3, fig. 2). The first whorl has a diameter of 0.17 mm; the plane of coiling is tilted at an angle of 40° to the vertical and has the axial plane normal to the axial plane of the outer whorl. The second whorl has a diameter of 0.30 mm. The angle of the plane of coiling to the vertical cannot be determined in this section because the axial plane is parallel to the axial plane of the outer whorl, but the direction of coiling is reversed. Four septa are in this whorl. The third whorl has a diameter of 0.55 mm; the plane of coiling is tilted at an angle of 5° to the vertical. The fourth or outer whorl has a diameter of 1.42 mm and contains 5 double septa, which form a triangle; the base of this triangle is the outer wall of the test. The anterior septa (the septa facing the direction of coiling) and the test wall are very thick and alveolar. The posterior septa are thin. Some septa do not extend to the wall of the next inner whorl.

The wall is thick and coarsely fibrous or alveolar and has a thick, granular, porous tectumlike structure. The inside diameter of the proloculus is 0.053 mm, and the outside diameter is 0.105 mm; the average wall thickness is 0.027 mm. The wall structure of the proloculus is indistinct. The wall thickness of the second whorl is 0.039 mm, and there are 10 alveoli in 0.105 mm. The wall thickness of the third whorl is 0.052 mm, and 10 alveoli occupy 0.216 mm. The outer wall is 0.70 mm thick, and 10 alveoli occupy from 0.224 mm to 0.394 mm. The wall structure is easily distinguishable in axial section (pl. 3, figs. 1a, b), and the continuous turning of the plane of coiling may be seen as in the median section. There is no tunnel, and there are no chomata, as in the Fusulinidae, even though the wall structure is similar to that of the latter as well as to that of *Endothyra*. One also may note the relationship to *Endothyra* by observing the endothyroid juvenarium. A gradual change to a smaller ratio of axial length to diameter takes place from whorl to whorl. This change is typical of *Bradyina*. Occurrence of species is common.

The species differs from *Bradyina nautiliformis* Möller (1878, pl. 3, figs. 3, 4) by being slightly more compressed, having longer slitlike apertures along the suture lines, and having slits that are spaced farther apart. The species may closely resemble *B. holdenvillensis* Harlton (1927, pl. 2, fig. 1) if one uses the original description of *B. holdenvillensis* in comparing them. There is considerable difference, however, between *B. magna* and the type figure of *B. holdenvillensis*. In *B. magna* the chambers are less inflated and the manner of coil, which ranges from nautiloid to asymmetrically twisted in the outer whorl, can be easily distinguished, whereas the type figure of *B. holdenvillensis* does not clearly show the manner of coiling. Because the original description and figure of *B. holdenvillensis* show some discrepancies, and because the specimens from the Staunton formation are larger than *B. holdenvillensis*, they are identified as *B. magna*. Roth and Skinner (1930, p. 336) pointed out the probable close relationship of the two species when they named *B. magna*.

### Subfamily TETRATAXINAE Galloway, 1933

Species of the subfamily TETRATAXINAE from the lower Staunton formation

1a. Test not conical
........................................ *Globivalvulina biserialis* Cushman and Waters, page 36

1b. Test conical
  2a. Test with four chambers to a whorl
    3a. Valvular projections without lips
      4a. Lateral slopes concave..... *Tetrataxis concava* Galloway and Ryniker, page 37
      4b. Lateral slopes convex...... *Tetrataxis biconvexa* n. sp., page 38

3b. Valvular projections with lips.. *Tetrataxis labiata* n. sp., page 38
2b. Test with two chambers to a whorl. *Tetrataxis corona* Cushman and Waters, page 39
2c. Test with eight or more chambers to a whorl ...................... *Polytaxis laheei* Cushman and Waters, page 40

**Genus GLOBIVALVULINA Schubert, 1921**

Genotype (monotypic), *Globivalvulina bulloides* (Brady) equals *Valvulina bulloides* Brady, 1876, Palaeont. Soc. Pub., v. 30, p. 89, pl. 4, figs. 12-15. Upper Pennsylvanian, Iowa.

*Globivalvulina* Schubert, 1921, Palaeont. Zeitschr., v. 3, p. 153.

Early test endothyroid; later, low trochoid spiral which becomes biserial in specialized forms is developed; wall calcareous, fibrous, and alveolar, not agglutinated; aperture lobate and opens into vestibule near middle of large ventral side.

**Globivalvulina biserialis Cushman and Waters**

Plate 3, figures 3a-c, 4, 5

*Globivalvulina biserialis* Cushman and Waters, 1928a, Cushman Lab. Foram. Research Contr., v. 4, pt. 3, p. 64-65, pl. 8, figs. 7a-c. Upper Pennsylvanian, Young County, Tex.—Galloway and Ryniker, 1930, Okla. Geol. Survey Circ. 21, p. 16, pl. 2, figs. 10-11; pl. 3, figs. 2a-c. Lower Pennsylvanian, Latimer County, Okla.—Cushman and Waters, 1930, Tex. Univ. Bull. 3019, p. 70, pl. 8, figs. 1-5.—Plummer, 1945, Tex. Univ. Bull. 4401, p. 248. Lower Pennsylvanian, Brady, Tex.—Plummer, 1948, Am. Midland Naturalist, v. 39, no. 1, p. 170, figs. 1-3.

*Globivalvulina ovata* Cushman and Waters, 1928a, Cushman Lab. Foram. Research Contr., v. 4, pt. 3, p. 65, pl. 8, figs. 8a-c. Upper Pennsylvanian, Texas.

Test ovate; juvenarium begins as low-spired endothyroid coil and changes abruptly to biserial; test is at same time coiled in expanding whorl, and latter plane of coiling is perpendicular to plane of biserial arrangement of chambers; chambers slightly inflated and rapidly expanding; only juvenarium and 5 to 7 chambers visible on ventral side; wall calcareous and transversely fibrous; 1 aperture for each terminal chamber opening into large 3-lobed vestibule on ventral side. Longest diameter 0.45 mm; shortest diameter 0.42 mm.

Two sections, one perpendicular and the other parallel to the adult biserial part of the test, were made. The perpendicular section (pl. 3, fig. 4) shows a "Y" septal arrangement along the dorsal side that is caused by overlap of chambers. The wall is thick and has been little altered, and the very fine transverse fibers may be distinguished clearly. The parallel section shows the rapidly expanding biserial arrangement of chambers. The moderately large proloculus has an outside diameter of 0.035 mm and a wall thickness of 0.010 mm. The apertural opening cannot be seen in this section, but part of the lobations caused by the apertures are seen. Their arrangement indicates that probably only the aperture associated with the terminal chamber was functional; the previous aperture had been sealed off by the wall of the last chamber. If not, the penultimate aperture is deep in the vestibule and faces the wall of the terminal chamber. The wall is thick in both sections and tends to be like that of *Bradyina*, but it is not as coarsely alveolar. It is more alveolar, however, than the wall in *Endothyra* or *Endothyranella*. Occurrence of species is rare to common.

As the wall has been considerably recrystallized in the section cut parallel to the biserial plane (pl. 3, fig. 5), transverse fibers are not as clearly seen as in the perpendicular section. This illustrates that granularity or lack of it has no specific meaning. The tectum can be seen in the perpendicular section. In addition, at the base of the last chamber there is a deposition of secondary skeletal material like an upper tectorium that also appears finely alveolar. The wall structure noted below under the genus *Polytaxis* has a similar appearance.

The species is characterized by the rapidly expanding biserial arrangement of the adult stage of the test, which in turn is coiled in a rapidly expanding open coil whose plane is perpendicular to the plane of the biserial chambers. Therefore, the juvenarium is beneath the terminal vestibule.

### Genus TETRATAXIS Ehrenberg, 1843

Genotype (monotypic), *Tetrataxis conica* Ehrenberg, 1843, K. preuss. Akad. Wiss., p. 106; 1854, Mikrogeologie, pl. 37, pt. 11, fig. 12. Lower Pennsylvanian, Tula, Russia.—Möller, 1879, Acad. Imp. Sci., St. Pétersbourg, Mém., ser. 7, v. 27, p. 71, pl. 2, fig. 3; pl. 7, figs. 1, 2 (topotypes).

*Valvulina* (part) of Brady, 1876, Palaeont. Soc. Pub., v. 30, p. 83.

Test trochoid; base flat or concave; 3 or 6 chambers for each whorl in juvenarium; juvenarium not tubular; typically 4 chambers to a whorl in adult stages, but in some chambers reduced to 3 and 2; all chambers visible on dorsal side, but only those of outer whorl seen on ventral side; wall calcareous and consists of dark, thin, fine-grained outer layer (tectum) and thick, alveolar inner layer (keriotheca); wall not arenaceous or agglutinated; apertures open into umbilicus on ventral side under valvular flaps.

#### Tetrataxis concava Galloway and Ryniker

Plate 3, figures 6a-c, 7

*Tetrataxis concava* Galloway and Ryniker, 1930, Okla. Geol. Survey Circ. 21, p. 18, pl. 3, figs. 6a-c. Lower Pennsylvanian, Latimer County, Okla.

Test depressed; has conical center; concave from apex to base; has general apical angle of 130°; concave ventrally; periphery lobulate; 6 chambers to whorl in juvenarium and 4 chambers in last whorl; chambers elongate and curved peripherally and radially broad ventrally; each chamber has toothlike projection into four-lobed central vestibule; upper surface minutely pitted; wall calcareous and has thin, dark, porous upper layer and thick, coarsely alveolar lower layer; 4 apertures open into ventral concavity, 1 for each chamber in outer whorl, beneath each radial projection. Diameter 0.48 mm to 1.06 mm; height from apex to base 0.23 to 0.31 mm. Occurrence of species is common.

The opening into the vestibule of some chambers is seen clearly in cross section (pl. 3, fig. 7). In such a section each coil is arranged in an imbricating fashion; thus most of the coil is beneath the previous whorl. The chambers taper inward and are deepest toward the outside of the test. They curve upward toward the dorsal surface. The wall is very thick and alveolar. As little recrystallization has occurred, the alveoli are distinct and unmistakable. There is a thin, dark upper layer. The species is characterized by the dorsally biconcave shape and a high conical juvenarium; in larger specimens the ratio of height to width increases considerably.

### Tetrataxis biconvexa n. sp.

Plate 3, figures 8a-c, 9

Test low mamillate spire with high center; biconvex dorsally and concave ventrally; four chambers per whorl around periphery, which is nonlobulate; outer chambers very narrow and long circumferentially; narrow toothlike valves project toward center; wall calcareous and consists of dark, thin upper layer (tectum) and thick lower layer, which is fibrous in early whorls and coarsely alveolar in later whorls; apertures low slits opening into umbilicus under valves. Average diameter 1.31 mm; height 0.64 mm. Occurrence of species is rare.

In cross section (pl. 3, fig. 9) the chambers are short and taper inward comparatively rapidly, and thus a proportionately broad vestibule is produced; the chambers are only slightly curved. The lower wall in the early whorls is a thick layer in which transverse fibers are clearly keriothecalike.

The species is characterized by its sigmoid curves on the lateral slopes, by its ratio of height to width of 2.0, by the long, sinuous, ropy appearance of the chambers on the dorsal side of the adult part, by the long narrow radial projections on the ventral surface, and by its large size. It was the largest *Tetrataxis* found in the fauna.

*Tetrataxis biconvexa* most closely resembles *T. maxima depressa* Schellwien (1898, p. 275, pl. 24, figs. 11a, b), but it differs primarily in its greater height in comparison to the diameter. One cannot tell from the type figure how many chambers are in the outer whorl. *T. maxima depressa* may be a *Polytaxis* just as *T. maxima* Schellwien (1898, p. 274, pl. 24, figs. 5-10).

*Tetrataxis biconvexa* is named for the biconvex lateral slopes that are seen in edge view.

### Tetrataxis labiata n. sp.

Plate 3, figures 10a-c, 11

Test low cone and has apical angle of about 110° to 120°, slightly concave slopes, lobulate periphery, and gently concave base; four unequal chambers, which ventrally appear about one-half as wide as their circumferential length, in outer whorl; wall calcareous and has thin, dark upper layer and thicker, transversely fibrous lower layer; 1 aperture from each chamber opens into 4-lobed vestibule beneath valvular projection; each valve has small lip. Average diameter 1.31 mm; height 0.64 mm. Occurrence of species is rare.

The chambers are large in cross section (pl. 3, fig. 11); they taper inward as in the other species of *Tetrataxis* and curve upward toward the dorsal surface but not as sharply as in *T. concava*. In the sectioned specimen the chambers are completely filled with relatively large grains of crystalline calcite as the result of infiltration. The infiltrated material can be distinguished from the skeletal material by the crystalline texture. The main test wall is composed of the thick, alveolar lower layer and the thin, darker upper or outer layer, as mentioned in the previous examples of *Tetrataxis*. The wall of *T.*

*labiata* has been altered more highly by recrystallization than those of the other examples, and thus the original wall structure in parts of the test has been destroyed. Occurrence of species is common.

The species varies considerably in the apical angle, but it is characterized by the low conical shape, the slightly concave slopes, the lobulate periphery, the shallow four-lobed vestibule, and the lips on the valves. It differs from *T. lata* Spandel (1901, fig. 6) in that the test is a lower cone and lacks the deep vestibule. *T. labiata* is named for the lips on the valves, which are its most diagnostic characteristic.

**Tetrataxis corona Cushman and Waters**

Plate 3, figures 12a-c, 13

*Tetrataxis corona* Cushman and Waters, 1928a, Cushman Lab. Foram. Research Contr., v. 4, pt. 3, p. 65 and 67, pl. 8, figs. 10a, b. Upper Pennsylvanian, Coleman County, Colo.—Cushman and Waters, 1928d, Jour. Paleontology, v. 2, p. 371, pl. 49, fig. 12. Upper Pennsylvanian, Sutton County, Tex.—Cushman and Waters, 1930, Tex. Univ. Bull. 3019, p. 75, pl. 7, figs. 3, 8. Upper Pennsylvanian, Young County, Tex.—Galloway and Ryniker, 1930, Okla. Geol. Survey Circ. 21, p. 17, pl. 3, figs. 5a-c. Lower Pennsylvanian, Latimer County, Okla.

Test depressed conical; has concave upper slopes in the adult and general apical angle of 140°; triangular in edge view in neanic specimens and has apical angle of 110°; ventral surface flat to slightly concave, and 2 valvular projections extend into 2-lobed vestibule; 5 to 6 whorls, 4 chambers per whorl in early part, and 2 chambers in last whorl; chambers broad ventrally and elongate peripherally; sutures slightly depressed; wall calcareous and has thin, dark upper layer (tectum) and thick, transversely fibrous and alveolar lower layer; apertures open under radial projections. Diameter 0.49 mm; height from apex to base 0.21 mm. Occurrence of species is rare.

In cross section (pl. 3, fig. 13) the chambers taper inward as in *T. concava*, but they do not curve upward. The wall is thick as compared with forms like *Endothyra* and *Endothyranella* but is relatively thin as compared with *Polytaxis* and other species of *Tetrataxis*. In the middle of the test dorso-ventrally one wall is excessively thick and shows the fibrous character well. As recrystallization has been only moderate, the original wall structure is clearly discernible.

The species is characterized by its small size, almost flat ventral surface, straight to slightly biconcave cross sectional outline, and only two chambers in the last whorl. The Staunton specimen seems to be exactly the same as the Atoka ones figured by Galloway and Ryniker, but they may not be the same as Cushman and Waters' species, which was described and illustrated inadequately.

**Genus POLYTAXIS Cushman and Waters, 1928**

Genoholotype, *Polytaxis laheei* Cushman and Waters, 1928b, Cushman Lab. Foram. Research Contr., v. 4, pt. 2, p. 51, pl. 7, fig. 7. Middle Pennsylvanian, Parker County, Tex.

Test low convexo-concave; all whorls may be seen on dorsal side; only chambers of outer whorl may be seen on ventral side; many chambers are in outer whorl, and one radial valvular projection for each chamber extends into central vestibule; chambers thin and peripherally short; juvenarium tetrataxoid; wall calcareous and fibrous; apertures open under narrow valvular projections into vestibule.

**Polytaxis laheei Cushman and Waters**

Plate 3, figures 14a, b; plate 4, figures 1, 2

*Polytaxis laheei* Cushman and Waters, 1928b, Cushman Lab. Foram. Research Contr., v. 4, pt. 2, p. 51, pl. 7, fig. 7. Middle Pennsylvanian, Parker County, Tex.—Warthin, 1930, Okla. Geol. Survey Bull. 53, p. 26, pl. 1, figs. 21a, b. Middle Pennsylvanian, east-central Oklahoma.—Cushman, 1933, Cushman Lab. Foram. Research Special Pub. 4, p. 171, pl. 18, fig. 22.

Test low and conical to flat; peripheral margin sharp and undulatory; dorsal surface shows entire coil to proloculus; ventral surface has outer whorl only; 3 to 4 chambers to a whorl in young part and 12 or 13 chambers to a whorl in adult part; each chamber has short valve extending toward concave depression on ventral side; parts of earlier valves may be seen lining vestibule; valves of most of inner whorls cause ventral side to appear papillate; wall calcareous and transversely fibrous; apertures open from under valves into vestibule on ventral surface. Diameter 1.67 to 3.46 mm. Occurrence of species is very abundant.

Two sections of the species were made; one is a cross section (pl. 4, fig. 1), as in the species of *Tetrataxis*, and the other is in the plane of the disc (pl. 4, fig. 2). The structure is basically that of *Tetrataxis*. The chambers are arranged in a low spiral coil, and each whorl imbricates beneath the previous whorl. In cross section the chambers taper to the vestibule, and the opening into the vestibule of some of the chambers can be seen. The chambers turn sharply up toward the dorsal side and have been infiltrated and now are filled with comparatively large crystals of calcite. In both sections the original wall structure is partly altered by recrystallization. In the ventral wall of each chamber in the cross section, the diameter of the crystals of calcite is about as thick as the ventral wall, but the wall is thin as compared to the dorsal wall. The dorsal wall is thick, and the grains of calcite are cryptocrystalline in size. The wall thus appears unusually dark in transmitted light.

In the specimen from which the section perpendicular to the plane of coiling was made, some of the chambers open into the central vestibule through a constricted opening, the aperture. The irregular undulatory circumferential outlines of the chamber walls, as well as the detail of the wall, are clearly shown. Only in a very few places is there direct evidence of fibers. There is, however, an orderly arrangement of the crystals, and thus the crystal boundaries are arranged in a straight line transverse to the wall. These interfaces suggest that fibers formerly were present, since they follow the same pattern as the fibers. The perpendicular section cuts through the vestibule, which like the vestibule in the cross-sectioned specimen is lined in a similar manner with a secondary deposit of calcite.

The species is characterized by its large size and the many chambers for each whorl, by the papillose appearance of the short radial projections from each chamber of the inner whorls, and by the large number of chambers about the periphery. One cannot distinguish *Polytaxis laheei* from the genus *Tetrataxis* on the basis of wall structure, chamber arrangement, or type of aperture, the three fundamental criteria ordinarily used to characterize genera of Foraminifera.

## Family NODOSINELLIDAE Rhumbler, 1895

### Genus EARLANDIA Plummer, 1930

Genoholotype, *Earlandia perparva* Plummer, 1930, Tex. Univ. Bull. 3019, p. 12, pl. 1, fig. 2. Upper Pennsylvanian, Wise County, Tex.

Test monothalamous; has bulbous proloculus and nearly straight tubular part; wall calcareous and granular to transversely fibrous, much as in *Endothyra;* aperture simple and at end of tube. Proloculus may have smaller or larger diameter than tubular part.

Because of the transversely fibrous type of wall found in the diverse species of the fauna, it is suspected that all Paleozoic Foraminifera referred to the genus *Hyperammina* are actually *Earlandia.* The type of *Hyperammina, H. elongata* Brady (1878, p. 433, pl. 20, fig. 2), is a Recent arenaceous form from the Arctic Sea.

#### Earlandia bulbosa (Cushman and Waters)

Plate 4, figures 3a-c

*Hyperammina bulbosa* Cushman and Waters, 1927b, Cushman Lab. Foram. Research Contr., v. 3, p. 109, 110, pl. 22, fig. 7. Middle Pennsylvanian, Clinton County, Mich.—Cushman and Waters, 1930, Tex. Univ. Bull. 3019, p. 34, pl. 2, figs. 4, 5. Upper Pennsylvanian, Coleman County, Tex.—Plummer, 1945, Tex. Univ. Bull. 4401, p. 220, pl. 15, fig. 36. Lower Pennsylvanian, Llano uplift, Tex.

*Hyperammina gracilis* Waters, 1927, Jour. Paleontology, v. 1, p. 130, pl. 22, figs. 4, 5. Lower Pennsylvanian, southern Oklahoma.

*Hyperammina gracilis* var. *rugosa* Waters, 1927, Jour. Paleontology, v. 1, p. 130, pl. 22, fig. 6. Lower Pennsylvanian, southern Oklahoma.

Test small and unilocular; has large, bulbous proloculus and thick tubular part; wall calcareous, finely granular, and transversely fibrous in favorable sections; surface finely granular; aperture simple and at end of tube. Diameter of proloculus 0.35 mm; total length 0.55 mm. Occurrence of species is rare.

Only two specimens were found, both of which were compressed and distorted. As part of the tube of both was broken off, it was impossible to tell the original total length. The remaining part of the test had been flattened and distorted. After 1 of the 2 specimens had been dissolved in hydrochloric acid, an estimated one-tenth or less of the original mass was left as an insoluble residue. A thin section of the other specimen (pl. 4, fig. 3c) was made to determine the character of the wall. The wall was composed almost exclusively of fine, granular calcite, and there were indications of fibrous structure in places, much as is seen in *Endothyra.* The wall has been recrystallized.

The wall of *Earlandia bulbosa* is not arenaceous but is composed entirely of crystalline calcite. Moreover, it is not coarsely textured as shown in Brady's type figure of *Hyperammina* (1878, pl. 20, fig. 2) from the Recent. As it seems unlikely that this genus would be so far ranging, the Pennsylvanian *Hyperammina bulbosa* is placed under the genus *Earlandia.*

The large, bulbous proloculus distinguishes *E. bulbosa* from other species of the genus, but it is not considered to be a generic character.

## Family FUSULINIDAE Möller, 1878

### Subfamily OZAWAINELLINAE Thompson and Foster, 1937

### Genus OZAWAINELLA Thompson, 1935

Genotype (designated by Thompson, 1935), *Ozawainella angulata* (Colani) equals *Fusulinella angulata* Colani, 1924, Indochine Service géol. Mém., v. 11, p. 74, 75, 132, 133, pl. 2, figs. 12-14, 16-18, 20, 21, 35. [Not pl. 2, figs. 4-11, 26, 34.] Permian? Indochina.

*Staffella* Ozawa [part], 1925, Tokyo Imp. Univ., Coll. Sci., Jour., v. 45, art. 4, p. 24.

*Ozawaina* Lee [part], 1927, Palaeontologica Sinica, ser. B, v. 4, p. 13.

*Orobias* Galloway and Harlton [not Eichwald, 1860], Jour. Paleontology, v. 2, p. 348-349.

*Ozawainella* Thompson, 1935, Jour. Paleontology, v. 9, p. 113-114.

Test small, lenticular, planispiral throughout, and involute to umbilicus; has angled back; wall calcareous and fibrous; has thin tectum and diaphanotheca and tectoria in higher forms; wall granular to transversely fibrous; test may have slight chomata; aperture absent. This genus differs from *Millerella* in having a sharp back and the outer whorl embracing to the umbilicus. *Ozawainella* differs from *Staffella* and *Pseudostaffella* in being discoidal, rather than subglobular, in shape.

#### Ozawainella ciscoensis (Harlton)

Plate 4, figures 4a-c, 5a-c, 6-8

*Staffella ciscoensis* Harlton, 1928, Jour. Paleontology, v. 1, p. 307, pl. 52, fig. 9. Upper Pennsylvanian, Eastland County, Tex.

*Orobias ciscoensis* Galloway and Harlton, 1928, Jour. Paleontology, v. 2, p. 350, pl. 45, fig. 11. Lower Pennsylvanian, Latimer County, Okla.—Galloway and Ryniker, 1930, Okla. Geol. Survey Circ. 21, p. 15, pl. 2, figs. 9a, b. Lower Pennsylvanian, Latimer County, Okla.—Warthin, 1930, Okla. Geol. Survey Bull. 53, p. 22, pl. 2, fig. 1. Middle Pennsylvanian, east-central Oklahoma.—Harlton, 1933, Jour. Paleontology, v. 7, p. 11, pl. 2, fig. 5. Lower Pennsylvanian, southeastern Oklahoma.

Test discoidal, slightly asymmetrical, involute to small, shallow umbilici, and nearly planispiral; peripheral margin sharp and in places slightly lobulate; 16 to 20 chambers in outer whorl; sutures slightly depressed and evenly curved and appear limbate where chambers are not completely filled with calcite; minutely pitted and thus has porous appearance noted by Harlton (1928, pl. 52, fig. 9); wall calcareous and fibrous; aperture probably absent.

As seen in a median section (pl. 4, figs. 6-8), *O. ciscoensis* consists of 4 or 5 volutions. The first volution ranges in height from 0.015 mm to 0.030 mm, the second from 0.022 mm to 0.044 mm, the third from 0.039 mm to 0.051 mm, and the fourth from 0.051 mm to 0.080 mm; the fifth has a height of 0.090 mm. There are 6 to 10 septa in the first whorl, 10 to 13 in the second, 13 to 17 in the third, 15 to 22 in the fourth, and 16 to 22 in the outer whorl. The wall is 0.004 mm to 0.007 mm thick in the first whorl, 0.006 mm to 0.008 mm in the second, 0.008 mm to 0.010 mm in the third, 0.010 mm to 0.011 mm in the fourth, and 0.017 mm in the fifth. As the wall consists of a thin tectum and finely granular to fibrous diaphanotheca and a thin outer tectorium, it has a thick appearance. The proloculus is small. It has an outside diameter ranging from 0.017 mm to 0.031 mm and a wall thickness ranging from 0.006 mm to 0.028 mm. The septa are slightly curved, thick, and extend nearly to the next inner whorl at a slightly oblique angle. There are 10 alveoli in about 0.021 mm in well-preserved parts of some sections where they can be observed.

Diameter is 0.24 mm to 0.78 mm, thickness 0.07 mm to 0.23 mm, and form ratio 0.30 to 0.37. Occurrence of species is very abundant.

The species is characterized by its diversity, the curved sutures, shallow umbilici, small size, and small form ratio. The specimens differ from the type in having a few less chambers. (The type figures by Harlton, 1928, pl. 52, figs. 9a-c, show 23 chambers.) As foreign material is illustrated in the umbilical area of the type figure, one cannot tell if it is umbilicate or umbonate. However, the Staunton specimens are not discordant with other specimens referred to this species, as illustrated by Galloway and Harlton (1928, pl. 45, figs. 11a-c). *O. ciscoensis* differs from *O. biumbonata* (Galloway and Harlton) (1928, pl. 45, fig. 10) in lacking the two umbos and usually having more chambers than *O. biumbonata*. *O. ciscoensis* differs from *O. radiata* (Brady) (1876, pl. 5, figs. 11, 12) in that *O. radiata* has a greater form ratio, is more asymmetrical in the outer whorl, and has an outer whorl that is more flaring and, therefore, more embracing. Some specimens from the Staunton fauna resemble *O. radiata* in the flaring, embracing character of the outer whorl, but because of the great difference in locality they are most likely not the same. In fact, those forms from the midcontinent that are identified as *O. radiata* (Galloway and Harlton, 1928, pl. 45, figs. 12a-c) probably are not the same as Brady's type from England.

## Subfamily SCHUBERTELLINAE Skinner, 1931

### Genus PSEUDOSTAFFELLA Thompson, 1942

Genotype (designated by Thompson, 1948) *Pseudostaffella needhami* Thompson, 1942, Am. Jour. Sci., v. 240, p. 411-413, pl. 3, fig. 13. Lower Pennsylvanian, Mud Springs Mountain, N. Mex.—Thompson, 1948, Kans. Univ. Paleont. Contr., Protozoa, art. 1, p. 38.

*Staffella* Ozawa[part], 1925, Tokyo Imp. Univ., Coll. Sci., Jour., v. 45, art. 4, p. 24.

Test small and subnautiloid to spheroidal; juvenarium endothyroid (asymmetrical) and large; tunnel path irregular; wall calcareous and fibrous and has thin tectum and thick diaphanotheca and thick upper tectorium; chomata are massive and are in outer whorl; aperture absent. This genus is placed in the Schubertellinae because it has an endothyroid juvenarium.

#### Pseudostaffella atokaensis (Thompson)

Plate 4, figures 9a-c, 10, 11

*Staffella atokensis* Thompson, 1935, Jour. Paleontology, v. 9, p. 117, pl. 13, figs. 6-10. Lower Pennsylvanian, Coal County, Okla.—Needham, 1937, N. Mex. School of Mines Bull. 14, p. 20, pl. 2, figs. 1, 2. Middle Pennsylvanian, Sierra County, N. Mex.

*Pseudostaffella atokensis* Thompson, 1948, Kans. Univ. Paleont. Contr., Protozoa, art. 1, p. 39. Lower Pennsylvanian, Oklahoma.

Test subnautiloid, asymmetrical, involute dorsally, and involute part way to umbilicus ventrally; 1½ whorls visible on ventral side, and 1 whorl visible on dorsal side; test umbilicate ventrally; periphery broadly rounded; 15 to 18 chambers in outer whorl; sutures flush with surface; wall calcareous and has thin tectum, thicker diaphanotheca, and thick upper tectorium; antetheca concave and asymmetrically crescentic in outline. Axial diameter from 0.19 mm to 0.89 mm; average form ratio 0.7.

Three complete volutions and part of a fourth are in the median section (pl. 4, fig. 10). The first whorl is 0.05 mm high, the second 0.07 mm, the third 0.12 mm, and the fourth 0.13 mm. The first whorl is at a large angle with later whorls, and the number of chambers cannot be determined; 10 chambers are in the second whorl, 13 are in the third, and 17 are in the fourth. The wall of the first volution is 0.027 mm thick, that of the second 0.032 mm, that of the third 0.029 mm, and that of the fourth 0.030 mm. The wall consists of a thin tectum, a thicker diaphanotheca, and a thick upper tectorium. Parts of the wall, as in a part of the third volution, appear thicker than they actually are because of deposition of secondary material infiltrated during the process of fossilization. The proloculus has an outside diameter of 0.113 mm and a wall thickness of 0.021 mm. The septa are thick and nearly radial. The slight anterior and posterior angles of the septa indicate incipient fluting.

The asymmetrical coil is obvious in axial section (pl. 4, fig. 11), as one notes the angle at which the chomata are tilted. The center of the tunnel is tilted at an angle of 72° to the vertical in the first whorl, at an angle of 27° in the second, and at an angle of 10° in the third and last whorl. The chomata are well developed and are about one-half the height of the whorl in all three volutions, but they are weakest in the second and strongest in the last volution. The tunnel angle of the first volution is 10°, of the second 11°, and of the third 11°. Occurrence of species is rare to common.

*Pseudostaffella atokaensis* is characterized by the asymmetrical, rather than typical nautiloid, coil of *Staffella*. This characteristic is obvious externally as well as in thin section. The feature is by no means unique with this species. The specimens most closely resemble *P. needhami* Thompson (1942, pl. 1, figs. 15-20; pl. 3, figs. 10-14), in which the axis of coiling turns in a horizontal plane in the first 2 whorls, and in which the last 2 whorls are nearly symmetrical. *P. atokaensis* has an axis of coiling which turns in a vertical plane. The size and form ratio of the two species are about the same. The species can be distinguished from *P. keytei maccoyensis* (Thompson) (1935, pl. 13, figs. 11-15) by its larger size, smaller tunnel angle, larger form ratio, and somewhat greater asymmetry of coil. (*P. keytei maccoyensis* has the first whorl or tunnel as much as 30° out of line.) *P. hollingsworthi* (Thompson) (1935, pl. 13, figs. 1-5) has a smaller proloculus, smaller form ratio, larger tunnel angle, and thinner walls than *P. atokaensis*.

*P. atokaensis* is preferable to the original spelling *P. atokensis*, because the species was named for the Atoka formation. It is unnecessary to drop the final "a" from the Atoka.

### Genus EOSCHUBERTELLA Thompson, 1937

Genotype (designated by Thompson, 1948) *Eoschubertella lata* (Lee and Chen) equals *Schubertella lata* Lee and Chen, 1930, in Lee, Chen, and Chu, Nat. Research Inst. Geology Mem. 9, p. 111, pl. 6, fig. 9. Middle Carboniferous, southeastern China.—Thompson, 1948, Kans. Univ. Paleont. Contr., Protozoa, art. 1, p. 33, pl. 4, figs. 1, 2.

*Schubertella* (*Eoschubertella*) Thompson, 1937, Jour. Paleontology, v. 11, p. 123-124.

Test minute and short fusiform to elliptical; polar regions bluntly rounded; juvenarium endothyroid (asymmetrical); small, spherical proloculus in microspheric forms and large, spherical proloculus in megaspheric forms; wall consists of tectum, diaphanotheca, and upper tectorium, rather than of tectum, no diaphanotheca, and lower as well as upper tectoria, as described by Thompson (1948, p. 33); 3 to 5 whorls in mature specimens; septa unfluted; tunnel irregular; polar regions have no axial filling.

*Eoschubertella* probably is the same genus as *Profusulinella;* both occur at the same horizons and in the same localities. Thompson (1948, p. 40) stated that "*Profusulinella* resembles *Eoschubertella* in several respects. However, *Eoschubertella* is smaller, generally is more loosely coiled and more highly ellipsoidal and has small chomata." These are scarcely generic differences. In most specimens from the Staunton formation, *E. mexicana* is elliptical in shape, whereas *P. fittsi* is typically fusoid in shape; this fact suggests that the *E. mexicana* are young rather than adult specimens. The size of the specimens also accords with this idea; *E. mexicana* does not exceed 0.4 mm in length, whereas *P. fittsi* is as much as 1.2 mm in length. The 2 species, *Eoschubertella mexicana* and *Profusulinella fittsi*, remain here, for the time being, under the 2 genera with which they were previously identified. They are distinguished on the basis of (1) size and (2) size and shape of proloculus.

### Eoschubertella mexicana Thompson

Plate 4, figures 12a, b; plate 5, figures 1-5

*Eoschubertella mexicana* Thompson, 1948, Kans. Univ. Paleont. Contr., Protozoa, art. 1, p. 79, pl. 28, figs. 1-8. Lower Pennsylvanian, Sierra County, N. Mex.

Test short, its poles pointed broadly; lateral slopes very convex; antetheca lower at equator than near poles. Form ratio varies from 1.3 to 1.8. Shape and form ratio of these specimens vary considerably. A typical specimen with a low form ratio (1.28) is 0.29 mm in diameter and 0.37 mm long. A typical specimen with a high form ratio (1.72) is 0.18 mm in diameter and 0.31 mm long.

Two volutions can be seen in the median section (pl. 5, fig. 4). The first whorl is 0.038 mm high and the second 0.086 mm. The septa are straight, radial, and thick and have an upper tectorium. There are 12 septa in the first volution and 18 in the second. In the first whorl the wall is 0.026 mm thick and in the second 0.018 mm. The wall is simple, consisting of tectum, diaphanotheca, and upper tectorium. Thompson (1948, p. 33) described the wall as consisting of only a tectum and upper and lower tectoria. Under high power in both the axial and median sections a diaphanotheca can be seen, but it is not as distinct as in *Fusulina* because of the small size of the specimens. The outside diameter of the proloculus is 0.160 mm; the wall is 0.026 mm. The large proloculus and small number of whorls, which are characteristic of all specimens found in the fauna, suggest that these are megaspheric forms of either *Schubertella* or *Profusulinella.* The juvenarium of *Eoschubertella* is asymmetrically coiled; in the forms with large proloculi, however, the asymmetrical juvenarium is not as distinct, owing to acceleration. There seems to be no observable difference between *Eoschubertella* and *Schubertella*, and the 2 may well be considered as 1 genus. There is no special taxonomic or stratigraphic advantage to having a genus *Eoschubertella*.

In axial section (pl. 5, fig. 5) there is no septal fluting, but the asymmetry of coiling may appear like fluting toward the poles. The chomata seem to be strongest in the first volution and weakest in the second. The tunnel angle is 24° in the first whorl and 32° in the second. No septal pores were observed. Occurrence of species is common.

### Genus PROFUSULINELLA Rauser-Cernoussova and Beljaev, 1936

Genoholotype, *Profusulinella pararhomboidea* Rauser-Cernoussova and Beljaev, 1936, in Rauser-Cernoussova, Beljaev, and Reitlinger, Acad. Sci. U. S. S. R. Trans., Polar Comm., v. 28, p. 175, 176, 221, pl. 1, fig. 6. Middle Carboniferous, northern Urals, Russia. [Holotype refigured by Thompson, 1948, pl. 6, fig. 2.]

Test small and ellipsoidal to short fusiform; poles bluntly rounded; juvenarium endothyroid in microspheric form; medium-sized, spherical proloculus in microspheric form and large, spherical proloculus in megaspheric form; wall consists of tectum, diaphanotheca, and upper tectorium; 4 to 7 whorls in mature specimens; septa slightly fluted in axial regions only; tunnel slightly irregular. The type figure obviously is a megaspheric specimen, which shows a more nearly planispiral juvenarium than do most other species.

### Profusulinella fittsi (Thompson)

Plate 5, figures 6-9

*Fusulinella fittsi* Thompson, 1935, Jour. Paleontology, v. 9, p. 300, pl. 26, figs. 1-6. Lower Pennsylvanian, Coal County, Okla.

*Profusulinella fittsi* Thompson, 1948, Kans. Univ. Paleont. Contr., Protozoa, art. 1, pl. 26, fig. 11. Lower Pennsylvanian, Coal County, Okla.

Typical examples of this species average 0.81 mm in diameter and 1.46 mm long; form ratio averages 2.0, ranging from 1.6 to 2.3; shell short and fusoid and has straight lateral slopes; ends bluntly rounded; axis straight; septal furrows broad and shallow; antetheca 0.13 mm high; antetheca most highly crenulated at ends; little or no fluting indicated near middle.

The following is a tabulated summary of characteristics seen in the sagittal section (pl. 5, fig. 8):

| No. of volution | Height of volution | Septal count | Wall thickness |
|---|---|---|---|
| 1 | 0.04 mm | 10 | 0.016 mm |
| 2 | 0.08 mm | 15 | 0.019 mm |
| 3 | 0.11 mm | 17 | 0.025 mm |
| 4 | 0.18 mm | 18 | 0.026 mm |

The wall is simple and consists of tectum, diaphanotheca, and upper tectorium. Thompson (1948, p. 39) described the wall of this genus, as he did for *Eoschubertella*, as consisting of only a tectum and upper and lower tectoria. Similarly, all sections made of the Staunton specimens showed under high magnification a definite thin diaphanotheca. Because of the small size of the specimens, the diaphanotheca may not be distinguishable in thick parts of the section. The lower layer of the wall has been misinterpreted as a lower tectorium instead of a diaphanotheca. In fact, Thompson (1948, pl. 27, fig. 13) showed a photograph of a section in which the lower layer is finely alveolar in part of the section, but he calls this a lower tectorium rather than a diaphanotheca. I cannot agree that the layer of the wall beneath the tectum is a tectorium instead of a diaphanotheca as in other Fusulinidae.

The proloculus in the figured specimen (pl. 5, fig. 8) has an outside diameter of 0.068 mm and a wall thickness of 0.006 mm.

The axial section (pl. 5, fig. 9) shows that the septal fluting is moderate to weak at the ends of the chambers and lacking in the middle of the chambers. The chomata cannot be seen in the first whorl because of the endothyroid juvenarium. The chomata are weakly developed in the second whorl, they are about one-half the height of the chamber in the third, and they are about two-thirds the height of the chamber in the fourth. The tunnel and chomata may be seen from the outside in some specimens. The tunnel angle in the second volution is 27°, in the third 30°, and in the fourth 32°. About seven chambers are shown in the first endothyroid coil. Occurrence of species is common.

The species may be distinguished from *P. munda* Thompson (1948, pl. 27, fig. 4; pl. 30, figs. 1-7) by its larger proloculus, smaller number of whorls, and narrower tunnel. It differs from *P. decora* Thompson (1948, pl. 27, figs. 5, 6, 12; pl. 29, figs. 5-30) by the larger proloculus, smaller number of whorls, and smaller amount of fluting. *P. oliviformis* (Thompson) (1935, pl. 26, figs. 10-13) has a smaller form ratio, a larger tunnel angle, and weaker chomata than *P. fittsi*. Because of the similarity of wall structure, and because the two forms occur together in the fauna, *P. fittsi* is likely the microspheric or adult form of *Eoschubertella mexicana*. The name *Profusulinella* has precedence over *Eoschubertella*.

### Subfamily FUSULININAE Rhumbler, 1895

### Genus FUSULINA Fischer, 1829

Genotype (designated by Yabe, 1903) *Fusulina cylindrica* Fischer de Waldheim, 1829, Soc. Imp. Nat. Moscou Bull., v. 1, p. 330; Oryctographie du Gouvernement de Moscou, 1830-1837, p. 126, pl. 13, figs. 1-5. Lower Pennsylvanian, Mjatschkowa, Russia.—Möller, 1878, Acad. Imp. Sci., St. Pétersbourg, Mém., ser. 7, v. 25, p. 51, pl. 1, fig. 2; pl. 7, fig. 1. (topotypes).—Schellwien, 1898, Palaeontographica, v. 44, p. 238.—Schellwien, 1908, Palaeontographica, v. 55, p. 161, pl. 13, figs. 1-11. (topotypes).—Yabe, 1903, Geol. Soc. Tokyo Jour., v. 10, p. 5.—Dunbar and Henbest, 1930, Am. Jour. Sci., v. 20, p. 357.

*Girtyina* [not of Staff] Lee, 1927, Palaeontologia Sinica, ser. B, v. 4, p. 22.

*Schellwienia* Staff and Wedekind, 1910, Upsala Univ., Geol. Inst., Bull., v. 10, p. 113. [Typonym of *Fusulina.*]

Test fusiform; wall calcareous and thin and has tectum and diaphanotheca and thin outer and inner tectoria; septal fluting strong and very strong in axial region; chomata weak to very strong; axial filling small; aperture absent.

**Fusulina novamexicana Needham**

Plate 5, figures 10-13

*Fusulinella* (*Girtyina*) aff. *F. ventricosa* Henbest, 1928, Jour. Paleontology, v. 2, p. 76, pl. 10, figs. 5, 7. Middle Pennsylvanian, Williamson County, Ill.
*Fusulina novamexicana* Needham, 1937, N. Mex. School of Mines Bull. 14, p. 23, pl. 2, figs. 11-15. Lower Pennsylvanian, Socorro Peak, N. Mex.—Dunbar and Henbest, 1942, Ill. Geol. Survey Bull. 67, p. 113, pl. 10, figs. 7-17. Lower Pennsylvanian, Socorro Peak, N. Mex.; middle Pennsylvanian, Jackson and Williamson Counties, Ill.

Species has external diameter as much as 2.25 mm, length of about 5 mm, and form ratio of 1.8 to 2.2; shape inflated fusoid and lateral slopes slightly concave; ends blunt and axis straight; septal furrows shallow; antetheca 0.2 mm high at center and 0.5 mm high at poles.

Eight volutions were noted in median section (pl. 5, fig. 12); the data for these are as follows:

| No. of volution | Height of volution | Septal count | Wall thickness |
|---|---|---|---|
| 1.................. | 0.04 mm | 13 | 0.027 mm |
| 2.................. | 0.08 mm | 21 | 0.040 mm |
| 3.................. | 0.11 mm | 29 | 0.053 mm |
| 4.................. | 0.17 mm | 32 | 0.047 mm |
| 5.................. | 0.19 mm | 35 | 0.080 mm |
| 6.................. | 0.20 mm | 40 | 0.050 mm |
| 7.................. | 0.23 mm | 50? | 0.050 mm |
| 8.................. | 0.27 mm | 55? | 0.053 mm |

The wall is composed of a thin tectum, thin diaphanotheca, and thin upper and lower tectoria. The proloculus has an outside diameter of 0.173 mm and a wall thickness of 0.06 mm.

In axial section (pl. 5, fig. 13) the fluting is moderate to weak in the middle of the chambers and is very strong at the ends of the chambers. The chomata are strong in volutions 1, 2, 3, 4, 5, and 6; they are weak in volutions 7 and 8. The tunnel angle is 5° in the first volution, 8° in the second, 12° in the third, 14° in the fourth, 17° in the fifth, 19° in the sixth, 19° in the seventh, and 30° in the eighth. No septal pores were observed. Occurrence of species is common.

*Fusulina novamexicana* has a greater form ratio than that of *F. girtyi* (Dunbar and Condra) (1927, pl. 2, figs. 1-4), which does not exceed 1.5, and which is more lemon-shaped; both species, however, are about the same size. *F. novamexicana* is larger and more ventricose than *F. euryteines* Thompson (1934, p. 310, pl. 12, figs. 4, 13, 14, 18).

**Fusulina haworthi (Beede) emend. Dunbar and Henbest**

Plate 5, figures 14-17

*Girtyina haworthi* Beede, 1916, Ind. Univ. Studies, v. 3, no. 29, p. 14. [Not *Fusulinella haworthi* Dunbar and Condra, 1927.] Middle Pennsylvanian, Fort Scott, Kans.

*Fusulina haworthi* White, 1932, Tex. Univ. Bull. 3211, p. 26, pl. 1, figs. 4-6. Middle Pennsylvanian, Palo Pinto County, Tex.—Dunbar and Henbest, 1942, Ill. Geol. Survey Bull. 67, p. 119, 121, pl. 12, fig. 1; pl. 14, figs. 1-20. Middle Pennsylvanian, Monroe, Greene, and St. Clair Counties, Ill.

*Fusulina stookeyi* Thompson, 1934, Iowa Univ. Studies in Nat. History, v. 16, p. 316, pl. 22, figs. 3, 15, 16, 21. [Lectoholotype, pl. 22, fig. 15, and lectoparatype, pl. 22, fig. 21, both designated by Dunbar and Henbest, 1942, Ill. Geol. Survey Bull. 67, p. 120.] Middle Pennsylvanian, Appanoose and Monroe Counties, Iowa.

The specimens from the Staunton formation are smaller than normal, and they are elongate, fusoid, and about 1.7 mm in diameter and 4.0 mm long. The form ratio is 2.33; the lateral slopes are straight, and the poles are sharply rounded; the axis is straight. The septal furrows are shallow, and the antetheca measures 0.33 mm at the center and 0.42 mm at the poles.

As shown in a median section (pl. 5, fig. 16) the test is composed of seven volutions; the data for these are as follows:

| No. of volution | Height of volution | Septal count | Wall thickness |
|---|---|---|---|
| 1.................. | 0.04 mm | 15 | 0.019 mm |
| 2.................. | 0.05 mm | 18 | 0.029 mm |
| 3.................. | 0.06 mm | 20 | 0.038 mm |
| 4.................. | 0.11 mm | 24 | 0.050 mm |
| 5.................. | 0.12 mm | 30 | 0.061 mm |
| 6.................. | 0.17 mm | 36 | 0.069 mm |
| 7.................. | 0.21 mm | 39 | 0.075? mm |

The wall is composed of a tectum, a diaphanotheca, and lower and upper tectoria. Because the thickness of the wall is irregular, the proloculus has an outside diameter ranging from 0.12 mm to 0.18 mm and a thickness ranging from 0.026 mm to 0.031 mm.

In axial section (pl. 5, fig. 17) the fluting appears moderately strong in the middle and very strong at the ends of the chambers; the fluting occupies the total height of the chambers. The chomata are strongly developed in all chambers. The tunnel angle measures 17° in the first chamber, 20° in the second, 22° in the third, 24° in the fourth, 25° in the fifth, and 28° in the sixth. No septal pores were observed. Occurrence of species is abundant.

*Fusulina haworthi* is distinguished from *F. kayi* Thompson (1934, pl. 21, figs. 1, 2, 4, 5, 8, 12-15, 19, 20) by its smaller form ratio; from *F. leei* Skinner (1931, pl. 30, figs. 4, 6) by its blunter poles and smaller form ratio; from *F. lucasensis* Thompson (1934, pl. 22, figs. 2, 9, 12, 17, 19) by its narrower tunnel angle and higher degree of fluting; from *F. euryteines* Thompson (1934, pl. 22, figs. 4, 13, 14, 18) by its higher, more sharply fluted septa; and from *F. pumila* Thompson (1934, pl. 22, figs. 6, 8, 10, 11) by its larger form ratio. All the foregoing species are based upon minute differences which may be subspecific. Because many of these species also occur at nearly the same horizons and localities, and because ranges of characteristics, such as the form ratio, overlap, identification is difficult.

### Genus WEDEKINDELLINA Dunbar and Henbest, 1933

Genotype (designated by Dunbar and Henbest, 1933) *Wedekindellina euthysepta* (Henbest) equals *Fusulinella euthusepta* Henbest, 1928, Jour. Paleontology, v. 2, p. 80, pl. 8, figs. 6-8b; pl. 9, figs. 1, 2, 5.

*Wedekindella* Dunbar and Henbest, 1930, Am. Jour. Sci., 5th ser., v. 20, p. 357. [Not Schindewolf, 1928.]

*Wedekindia* Dunbar and Henbest, 1931, Am. Jour. Sci., 5th ser., v. 21, p. 458. [Not Schindewolf, 1925.]

*Wedekindellina* Dunbar and Henbest, 1933, in Cushman, Foraminifera; their classification and economic use, p. 134.

Test small, thin, and fusiform; may have depression or groove over tunnel where thin spirotheca has been crushed; septa fluted only near ends; wall calcareous and fibrous and has tectum, diaphanotheca, and inner and outer tectoria; there is a large amount of axial filling, especially near poles; aperture absent.

### Wedekindellina euthysepta (Henbest)

Plate 5, figures 18-32

*Fusulinella euthusepta*[2] Henbest, 1928, Jour. Paleontology, v. 2, p. 80, pl. 8, figs. 6-8; pl. 9, figs. 1, 2. Middle Pennsylvanian, southern Illinois.

*Fusulinella minuta* Henbest, 1928, Jour. Paleontology, v. 2, p. 81, pl. 8, figs. 2-5. Middle Pennsylvanian, southern Illinois.

*Wedekindellina euthysepta* Dunbar and Henbest, 1930, Am. Jour. Sci., 5th ser., v. 20, p. 357, 364.—Thompson, 1934, Iowa Univ. Studies in Nat. History, v. 16, p. 282-285, pl. 20, figs. 1, 2, 7, 9, 12, 13, 17, 22, 24-27. Middle Pennsylvanian, Iowa.—Dunbar and Henbest, 1942, Ill. Geol. Survey Bull. 67, p. 98, pl. 8, figs. 1-23; pl. 9, figs. 1-4. Middle Pennsylvanian, southern Illinois.

*Wedekindellina minuta* Dunbar and Henbest, 1942, Ill. Geol. Survey Bull. 67, p. 100, pl. 10, figs. 1-6. Middle Pennsylvanian, southern Illinois.

*Wedekindellina dunbari* Thompson, 1934, Iowa Univ. Studies in Nat. History, v. 16, p. 285, pl. 20, figs. 3, 6, 15, 16, 20, 21. Middle Pennsylvanian, Iowa.

Externally shell moderately small, 4.00 mm long and 1.22 mm in diameter; form ratio 3.20; test fusoid in shape; lateral slopes straight and ends bluntly pointed; axis straight to slightly curved; septal furrows deeply entrenched; antetheca 0.09 mm high at center and 0.16 mm high at poles.

There were not enough specimens of the adult form to make a median section. In the axial section (pl. 5, fig. 30) eight volutions can be seen. Structurally the wall is composed of a tectum, diaphanotheca, and upper and lower tectoria. As in other members of *Wedekindellina*, the specimen shows no septal fluting in the axial region and only slight septal fluting in the polar regions. The chambers are filled with secondary shell material, especially along the axis of coiling and in the polar regions; this material obscures some detail of the test. The proloculus is small. It measures only 0.054 mm in the outside diameter and has a wall thickness of 0.023 mm. The chomata are absent in the first volution, weak in volutions 2, 3, 4, 5, and 6, moderately developed in the seventh volution, and strongly developed in the last volution. The tunnel angle is narrow and increases only slightly toward the outer whorls. The

[2] Misspelled for "euthy"; corrected by Dunbar and Henbest in 1930.

angle is 7° in the second volution, 8° in the third, 11° in the fourth, 14° in the fifth, 15° in the sixth, 17° in the seventh, and 20° in the eighth.

The description and discussion that follow are limited to those smaller forms which formerly were referred to *Wedekindellina minuta*. The axial length may range from 0.63 mm to 1.40 mm. A typical specimen measures 1.14 mm along the axial length and has a diameter of 0.43 mm; the form ratio is 2.65. The form ratio ranges from 2.54 to 3.47 in 27 specimens. The test is fusoid in shape and the lateral slopes are mostly straight. They may range, however, from slightly concave to slightly convex. The ends are mostly blunt but are sharp in a few specimens. The ends of some specimens appear blunter than normal because the tips have been worn down or broken off. The septal furrows are moderately shallow. The antetheca is only 0.058 mm high in the middle and 0.067 mm high near the poles. The specimens are smooth and show only a slight crenulation near the poles.

In the specimen from which the median section (pl. 5, fig. 31) was made there are five volutions; the data for these are as follows:

| No. of volution | Height of volution | Septal count | Wall thickness |
|---|---|---|---|
| 1.................... | 0.029 mm | 8 | 0.009 mm |
| 2.................... | 0.032 mm | 12 | 0.011 mm |
| 3.................... | 0.033 mm | 14 | 0.016 mm |
| 4.................... | 0.064 mm | 16 | 0.018 mm |
| 5.................... | 0.073 mm | 18 | 0.013 mm |

The wall consists of a thin tectum and diaphanotheca and relatively thick upper and lower tectoria. The wall of the outer whorl, which has no upper tectorium and only a thin lower tectorium, is thinner than the walls of the other whorls. The proloculus, though small, is proportionately large when one considers the size of the specimen. It has an outside diameter of 0.078 mm and a wall thickness of 0.008 mm. The septa are straight and much thickened by secondary wall material, even in the outer whorl where the inner tectorium is only poorly developed. The average thickness of the septa in the inner whorls is estimated to be about 1½ times the wall thickness.

In the axial section (pl. 5, fig. 32) there is no septal fluting in the middle of the chambers. There are only slight indications of fluting at the polar ends of the chambers, but this fluting is mostly obscured by deposition of secondary axial filling. Six whorls are shown; the chomata are weak in each. The chomata consistently occupy about one-third of the height of the whorl. The tunnel angle of the first volution is 11°, of the second 11°, of the third 13°, of the fourth 15°, of the fifth 18°, and of the sixth 18°. Occurrence of species is very abundant.

*Wedekindellina minuta* most closely resembles *W. euthysepta* (Henbest) and is distinguished from the latter only in the smaller size and in the fewer number of whorls. Dunbar and Henbest (1942, p. 101) noted the close similarity between the two forms and suggested that *W. minuta* might be the young of *W. euthysepta*. Such an idea seems to be borne out by several characteristics of the specimens from this fauna. First, *W. minuta* is associated with *W. euthysepta* in the Stonefort fauna of Illinois, reported by Dunbar and Henbest, as well as in the Staunton fauna of Indiana. Secondly, the data regarding form ratio, septal count, height of volutions, etc. agree well in both forms.

Thirdly, *W. minuta* is smaller and, therefore, has fewer whorls, as would be expected in a young specimen or as would be expected in a megaspheric specimen. Fourthly, ontogenetic series may be made (pl. 5, figs. 18-29) for *W. minuta* in which the axial length is shown to range from 0.44 mm to 1.45 mm. *W. euthysepta* measures 4.00 mm along the axial length; there is an obvious break in the progressive increase of size in the series between the *W. minuta* and *W. euthysepta* forms. Only two of the larger specimens were found, whereas a large number of smaller forms were found. Perhaps if the *W. euthysepta* forms were more abundant, a complete unbroken series between the two forms could be made. Dunbar and Henbest (1942, p. 101) pointed out that *W. minuta* has a large proloculus for its size; from their own data, however, it is shown that the proloculus of *W. euthysepta* varies considerably in size and that it may be even as large as that in *W. minuta.* The material from Indiana also seems to bear out the similarity of proloculi diameters measured in the two forms. For comparison, the sizes of proloculi of specimens from the described material and from the data given in Dunbar and Henbest's paper (1942, p. 98, 101) are as follows:

| Specimen No. | Size of proloculus | |
|---|---|---|
| | *W. euthysepta* | *W. minuta* |
| After Dunbar and Henbest | | |
| 1 | 0.040 mm | 0.042 mm |
| 2 | 0.042 mm | 0.045 mm |
| 3 | 0.045 mm | 0.065 mm |
| 4 | 0.047 mm | |
| 5 | 0.048 mm | |
| 6 | 0.050 mm | |
| 7 | 0.052 mm | |
| 8 | 0.062 mm | |
| 9 | 0.076 mm | |
| Staunton fauna | | |
| 1 | 0.054 mm | 0.050 mm |
| 2 | 0.086 mm | 0.069 mm |
| 3 | | 0.072 mm |

The measurements for *W. minuta* attributed to Dunbar and Henbest are averages of their measurements. They measured the proloculi in two directions because of the irregularity of shape. These figures are given to show that *W. minuta* probably is a young stage and not a megaspheric stage of *W. euthysepta.* The proloculus is proportionately larger in *W. minuta.* The correlation of proloculi probably further indicates some relationship between the two forms and gives some idea of the range of variability of specimens.

Because of the concurrent association of *W. euthysepta* and *W. minuta* in the Stonefort limestone of Illinois and the Staunton formation of Indiana, and because of the morphologic similarities, I suggest, as Dunbar and Henbest (1942, p. 101) first pointed out, that the two species are probably different growth stages of the same species. It is unfortunate, however, that there is such a large break in the ontogenetic series between the two forms. However, a few ontogenetic series from other localities that show a complete gradation from the *W. minuta* forms to the *W. euthysepta* forms have been prepared and are in the micropaleontologic collections at Indiana University. For that reason *W. minuta* is placed in synonymy with *W. euthysepta*, as suggested by Dunbar and Henbest (1942, p. 101).

## SELECTED BIBLIOGRAPHY


Beede, J. W., 1916, New species of fossils from the Pennsylvanian and Permian rocks of Kansas and Oklahoma: Ind. Univ. Studies, v. 3, no. 29, 15 p.

Brady, H. B., 1876, A monograph of Carboniferous and Permian Foraminifera (the genus *Fusulina* excepted): Palaeont. Soc. Pub., v. 30, 166 p., 12 pls.

———, 1878, On the Reticularian and Radiolarian Rhizopoda (Foraminifera and Polycystina) of the North Polar Expedition of 1875-1876: Annals and Mag. Nat. History, 5th ser., v. 1, p. 425-440, 2 pls.

Brown, Thomas, 1843, The elements of fossil conchology: 133 p., 12 pls., London, Houlston and Stoneman.

Chernysheva, N. E., 1940, On the stratigraphy of the Lower Carboniferous Foraminifera in the Makarovski district of the South Ural: Soc. naturalistes Moscou Bull., v. 48 (Sec. géol., v. 18), p. 129 (Russian); p. 135 (English).

Colani, M., 1924, Nouvelle contribution à l'études des fusulinidés de l'Extreme-Orient: Indochine Service géol. Mém., v. 11, p. 9-191, 29 pls.

Cooper, C. L., 1947, Upper Kinkaid (Mississippian) microfauna from Johnson County, Ill.: Jour. Paleontology, v. 21, p. 81-94, 5 pls., 1 text fig.

Cushman, J. A., 1927, The designation of some genotypes in the Foraminifera: Cushman Lab. Foram. Research Contr., v. 3, pt. 4, p. 188-190.

———, 1933, Foraminifera; their classification and economic use: Cushman Lab. Foram. Research Special Pub. 4, 2d ed., 349 p., 31 pls.

———, 1948, Foraminifera; their classification and economic use: 4th ed., 605 p., 86 pls., 9 text figs., Cambridge, Harvard Univ. Press.

———, and Waters, J. A., 1927a, Arenaceous Palaeozoic Foraminifera from Texas: Cushman Lab. Foram. Research Contr., v. 3, pt. 3, p. 146-155, 2 pls.

———, 1927b, Pennsylvanian Foraminifera from Michigan: Cushman Lab. Foram. Research Contr., v. 3, pt. 2, p. 107-110, 2 pls.

———, 1928a, Additional Cisco Foraminifera from Texas: Cushman Lab. Foram. Research Contr., v. 4, pt. 3, p. 62-67, 1 pl.

———, 1928b, Some Foraminifera from the Pennsylvanian and Permian of Texas: Cushman Lab. Foram. Research Contr., v. 4, pt. 2, p. 31-55, 4 pls.

———, 1928c, The development of *Climacammina* and its allies in the Pennsylvanian of Texas: Jour. Paleontology, v. 2, p. 119-130, 4 pls.

———, 1928d, Upper Paleozoic Foraminifera from Sutton County, Tex.: Jour. Paleontology, v. 2, p. 358-371, 3 pls.

———, 1930, Foraminifera of the Cisco group of Texas: Tex. Univ. Bull. 3019, p. 22-81, 11 pls.

Dunbar, C. O., and Condra, G. E., 1927, The Fusulinidae of the Pennsylvanian system in Nebraska: Nebr. Geol. Survey Bull. 2, 2d ser., 135 p., 15 pls., 13 text figs.

Dunbar, C. O., and Henbest, L. G., 1930, The fusulinid genera *Fusulina*, *Fusulinella* and *Wedekindella*: Am. Jour. Sci., 5th ser., v. 20, p. 357-364, 1 text fig.

———, 1931, *Wedekindia*, a new fusulinid name: Am. Jour. Sci., 5th ser., v. 21, p. 458.

———, 1942, Pennsylvanian Fusulinidae of Illinois: Ill. Geol. Survey Bull. 67, 218 p., 23 pls., 13 text figs.

Ehrenberg, C. G., 1843, Über die Verbreitung des jetzt wirkenden kleinsten organischen Lebens in Asien, Australien und Afrika und über die vorherrschende Bildung auch des Oolithakalkes jer Juraformation aus des kleinen polythalamischen Thieren: K. preuss. Akad. Wiss., p. 100-106.

———, 1854, Mikrogeologie: Leipzig, L. Voss, 374 p., 40 pls.

Ellis, B. F., and Messina, A. R., 1940-1956, Catalogue of Foraminifera: 51 v., New York, Am. Mus. Nat. History.

Fischer de Waldheim, Gotthelf, 1829, Sur les cephalopodes fossiles de Moscou et de ses environs, en montrant des objets en nature: Soc. Imp. Nat. Moscou Bull., v. 1, p. 300-362.

———, 1830-1837, Oryctographie du Gouvernement de Moscou: 202 p., 62 pls., Moscow, Auguste Semen.

Fuller, M. L., and Ashley, G. H., 1920, Description of the Ditney quadrangle: U. S. Geol. Survey Geol. Atlas, folio 84, 8 p., maps.

Galloway, J. J., 1933, Manual of Foraminifera: 483 p., 42 pls., Bloomington, Ind., Principia Press, Inc.

———, and Harlton, B. H., 1928, Some Pennsylvanian Foraminifera of Oklahoma, with special reference to the genus *Orobias*: Jour. Paleontology, v. 2, p. 338-357, 2 pls.

———, 1930, *Endothyranella*, a genus of Carboniferous Foraminifera: Jour. Paleontology, v. 4, p. 24-28.

Galloway, J. J., and Ryniker, Charles, 1930, Foraminifera from the Atoka formation of Oklahoma: Okla. Geol. Survey Circ. 21, 36 p., 5 pls.

Gubler, J., 1934, Structure et sécrétion du test des Fusulinidés: Annales de Protistologie, tome 4, p. 1-24.

Harlton, B. H., 1927, Some Pennsylvanian Foraminifera of the Glenn formation of southern Oklahoma: Jour. Paleontology, v. 1, p. 15-27, 5 pls.

———, 1928, Pennsylvanian Foraminifera of Oklahoma and Texas: Jour. Paleontology, v. 1, p. 305-310, 2 pls.

———, 1933, Micropaleontology of the Pennsylvanian Johns Valley shale of the Ouachita Mountains, Okla., and its relationship to the Mississippian Caney shale: Jour. Paleontology, v. 7, p. 3-29, 7 pls.

Henbest, L. G., 1928, Fusulinellas from the Stonefort limestone member of the Tradewater formation: Jour. Paleontology, v. 2, p. 70-85, 3 pls., 2 text figs.

———, 1935, *Nanicella*, a new genus of Devonian Foraminifera: Wash. Acad. Sci. Jour., v. 25, p. 34-35.

———, 1953, The name and dimorphism of *Endothyra bowmani* Phillips 1846: Cushman Foundation Foram. Research Contr., v. 4, pt. 2, p. 63-65, 2 figs.

Howchin, Walter, 1895, Carboniferous Foraminifera of Western Australia, with descriptions of new species: Royal Soc. South Australia Trans. and Proc., v. 19, p. 194-198, 1 pl.

Krumbein, W. C., and Sloss, L. L., 1951, Stratigraphy and sedimentation: 497 p., 122 figs., San Francisco, W. H. Freeman and Company.

Lee, J. S., 1927, Fusulinidae of North China: Palaeontologia Sinica, ser. B., v. 4, p. 1-123, 24 pls.

———, Chen, S., and Chu, S., 1930, The Huanglung limestone and its fauna: Nat. Research Inst. Geology Mem. 9, p. 85-143, 14 pls.

Marple, M. F., 1955, Small Foraminifera of the Pottsville formation in Ohio: Ohio Jour. Sci., v. 55, p. 81-89, 43 figs., 1 table.

Miller, A. K., and Carmer, A. M., 1933, Devonian Foraminifera from Iowa: Jour. Paleontology, v. 7, p. 423-431.

Möller, V. V., 1878, Die Spiral-Gewundenen Foraminiferen des Russischen Kohlenkalks: Acad. Imp. Sci., St. Pétersbourg, Mém., 7th ser., v. 25, p. 1-147, 15 pls.

———, 1879, Die Foraminiferen des Russischen Kohlenkalks: Acad. Imp. Sci., St. Pétersbourg, Mém., 7th ser., v. 27, p. 1-131, 7 pls., 30 text figs.

Moore, R. C., and others, 1944, Correlation of Pennsylvanian formations of North America: Geol. Soc. America Bull., v. 55, p. 657-706, 1 pl.

Moore, R. C., Lalicker, C. G., and Fischer, A. G., 1952, Invertebrate fossils: 766 p., 454 figs., New York, McGraw-Hill Book Company, Inc.

Needham, C. E., 1937, Some New Mexico Fusulinidae: N. Mex. School of Mines Bull. 14, p. 1-88, 12 pls., 1 text fig.

Ozawa, Yoshiaki, 1925, On the classification of Fusulinidae: Tokyo Imp. Univ., Coll. Sci., Jour., v. 45, art. 4, p. 1-26, 4 pls., 3 text figs.

Phillips, John, 1846, On the remains of microscopic animals in the rocks of Yorkshire: Geol. and Polytech. Soc., West Riding, Yorkshire, Proc. for 1844-45, Leeds, v. 2, p. 277, 1 pl.

Plummer, H. J., 1930, Calcareous Foraminifera in the Brownwood shale near Bridgeport, Tex.: Tex. Univ. Bull. 3019, p. 5-21, 1 pl., 3 text figs.

———, 1945, Smaller Foraminifera in the Marble Falls, Smithwick, and Lower Strawn strata around the Llano uplift in Texas: Tex. Univ. Bull. 4401, p. 209-271, 3 pls., 16 text figs.

———, 1948, Morphology of *Globivalvulina*: Am. Midland Naturalist, v. 39, p. 169-173, 5 figs.

Rauser-Cernoussova, D. M., Beljaev, G. M., and Reitlinger, E. A., 1936, Die oberpalaeozoischen Foraminiferen aus dem Petschora-Lande: Acad. sci. U. S. S. R. Trans., Polar Comm., p. 159-232, 6 pls.

Roth, Robert, and Skinner, John, 1930, The fauna of the McCoy formation, Pennsylvanian, of Colorado: Jour. Paleontology, v. 4, p. 332-352, 4 pls.

Schellwien, Ernst, 1898, Die Fauna des Karnischen Fusulinenkalks, Teil. 2, Foraminifera: Palaeontographica, v. 44, p. 237-282, 8 pls.

———, 1908, Monographie der Fusulinen; Teil 1—Die Fusulinen des russisch-arktischen Meeresgebietes: Palaeontographica, v. 55, p. 145-194, 8 pls.

Schubert, R. J., 1909, Zur Geologie des österreichischen Velebit: Jahrb. K. K. Geol. Reichs. for 1908, Wien, v. 58, p. 345-386, 1 pl.

———, 1921, Palaeontologische Daten zur Stammesgeschichte der Protozoen: Palaeont. Zeitschr., v. 3, p. 129-188.

Scott, H. W., Zeller, Edward, and Zeller, D. N., 1947, The genus *Endothyra*: Jour. Paleontology, v. 21, p. 557-562, 2 pls., 2 text figs.

Skinner, J. W., 1931, Primitive fusulinids of the midcontinent region: Jour. Paleontology, v. 5, p. 253-259, 1 pl., 1 text fig.

Spandel, Erich, 1901, Die Foraminiferen des Permo-Carbon von Hooser, Kansas, Nordamerika: Naturh. Gessell. Nürnberg, Festschrift, p. 175-194, 10 figs.

Staff, Hans von, and Wedekind, R., 1910, Der oberkarbone Foraminiferen-sapropelit Spitzbergens: Upsala Univ., Geol. Inst., Bull., p. 81-123, 3 pls., 2 text figs.

Thomas, A. O., 1931, Late Devonian Foraminifera from Iowa: Jour. Paleontology, v. 5, p. 40-41, 1 pl.

Thompson, M. L., 1934, The fusulinids of the Des Moines series of Iowa: Iowa Univ. Studies in Nat. History, v. 16, p. 277-329, 4 pls.

———, 1935, The fusulinid genus *Staffella* in America: Jour. Paleontology, v. 9, p. 111-120, 1 pl.

———, 1936, Pennsylvanian fusulinids from Ohio: Jour. Paleontology, v. 10, p. 673-683, 2 pls.

———, 1937, Fusulinids of the subfamily Schubertellinae: Jour. Paleontology, v. 11, p. 118-125, 1 pl.

———, 1942, New genera of Pennsylvanian fusulinids: Am. Jour. Sci., v. 240, p. 403-420, 3 pls.

———, 1947, Stratigraphy and fusulinids of pre-Desmoinesian Pennsylvanian rocks, Llano uplift, Tex.: Jour. Paleontology, v. 21, p. 147-164, 3 pls., 2 text figs.

———, 1948, Studies of American fusulinids: Kans. Univ. Paleont. Contr., Protozoa, art. 1, 184 p., 38 pls., 8 text figs.

Warthin, A. S., Jr., 1930, Micropaleontology of the Wetumka, Wewoka, and Holdenville formations: Okla. Geol. Survey Bull. 53, 94 p., 7 pls.

Waters, J. A., 1927, A group of Foraminifera from the Dornick Hills formation of the Ardmore Basin: Jour. Paleontology, v. 1, p. 129-133, 1 pl.

———, 1928, A group of Foraminifera from the Canyon division of the Pennsylvanian formation in Texas: Jour. Paleontology, v. 1, p. 271-275, 1 pl.

White, C. A., 1884, The fossils of the Indiana rocks, no. 3: Ind. Dept. Geology and Nat. History, Ann. Rept. 13, pt. 2, p. 107-180, 17 pls. on p. 232-265.

White, M. P., 1932, Some Texas Fusulinidae: Tex. Univ. Bull. 3211, 104 p., 10 pls., 3 text figs.

Wood, H. A., 1948, The structure of the wall of the test in the Foraminifera; its value in classification: Geol. Soc. London Quart. Jour., no. 104, p. 229-255, 3 pls.

Wray, J. L., 1952, Endothyroid Foraminifera from the Greenbrier series (Mississippian) of northern West Virginia: Jour. Paleontology, v. 26, p. 946-952, 20 figs.

Yabe, Hisakatsu, 1903, On a Fusulina-limestone with Helicoprion in Japan: Geol. Soc. Tokyo Jour., v. 10, p. 1-13, 1 pl.

Zeller, D. E. N., 1953, Endothyroid Foraminifera and ancestral fusulinids from the type Chesterian (upper Mississippian): Jour. Paleontology, v. 27, p. 183-199, 3 pls., 9 text figs., 1 chart, 3 tables.

Zeller, E. J., 1950, Stratigraphic significance of Mississippian endothyroid Foraminifera: Kans. Univ. Paleont. Contr., Protozoa, art. 4, 23 p., 6 pls.

# GLOSSARY

*Acceleration.* The tendency of more highly evolved organisms to pass rapidly through ancestral stages or to leave out or skip over early phylogenetic stages in their ontogeny.

*Agglutinated.* Composed of foreign materials cemented together.

*Alveolar.* Composed of parallel elongated spaces or cells, as in the wall of *Bradyina* or *Triticites.*

*Antetheca.* The terminal septum of the last formed chamber in the Fusulinidae.

*Aperture.* The one or more major openings to the outside of the test.

*Appression.* Refers to the tendency of certain Foraminifera to become tightly coiled. This tendency results in an involute condition, the condition of being pressed closely together, as the chambers and coils of the Fusulinidae.

*Arenaceous.* Composed of fine sand grains cemented together.

*Axial filling.* A deposit of secondary calcite along the axis, especially toward the polar regions, of some of the Fusulinidae, as in *Wedekindellina.*

*Axial section.* A thin section of a Foraminifera cut perpendicularly to the median section to show the proloculus and to include the entire axis.

*Axis.* An imaginary line about which coiling takes place.

*Back.* The profile of a Foraminifera as seen in an edge or apertural view; sometimes it is incorrectly referred to as the periphery.

*Choma*, pl. *chomata.* Secondary shell material which demarks the tunnel in the Fusulinidae.

*Cosmopolitan.* Applied to a fauna composed of species of wide geographic range.

*Dextral.* Coiling in a clockwise manner, or right handed.

*Diaphanotheca.* A moderately thin transparent layer with fine transverse fibers; it is found in the wall of most small Paleozoic Foraminifera and in the simple Fusulinidae.

*Dwarfed fauna.* A fauna consisting of completely developed specimens which have been retarded in growth by adverse conditions of environment.

*Endothyroid.* Like *Endothyra*, especially with reference to the asymmetrical manner of coiling.

*Endothyroid juvenarium.* The early whorl of a Foraminifera which has the appearance and character of *Endothyra;* found in *Profusulinella, Globivalvulina*, and *Bradyina.*

*Endothyroid stage.* The early stage which is morphologically the same as *Endothyra* in biformed Foraminifera, such as *Endothyranella.*

*Ephebic.* Pertaining to a specimen in the adult or mature stage of development in its life history.

*Evolute.* A loosely appressed coil in which the outer whorl does not cover the inner whorls, or the tendency to uncoil.

*Evolution.* The progressive changes in organisms during geologic time.

*Fibrous.* Having small transverse threads in the walls of most small Paleozoic Foraminifera and in the diaphanotheca of many fusulines.

*Fluting.* The convoluted or undulatory condition of the septa in many Fusulinidae.

*Foramen*, pl. *foramina.* The opening between chambers in Foraminifera; not the pores in the walls of the test.

*Form ratio.* In the Fusulinidae, the axial length divided by the median diameter, preferably expressed as a single number (2.2), rather than by 2 numbers separated by a colon (1:2.2).

*Fusiform.* Same as fusoid.

*Fusoid* or *fusiform.* Spindle shaped, or pointed at both ends, as in *Fusulina* or *Triticites.*

*Gerontic.* Pertaining to a specimen in the old-age or senile stage of its life history.

*Glomospiral.* Coiled like a ball of twine with an ever-changing axis.

*Hyaline.* Vitreous or glassy; may be either transparent or translucent. Refers to Foraminifera with calcareous perforate walls.

*Involute.* Closely appressed or more tightly coiled where the outer whorl embraces the inner whorls, as in *Bradyina.*

*Isomorph.* An organism similar in structure or shape to some other unrelated organism.

*Juvenarium,* pl. *juvenaria.* The proloculus and initial whorl or first few chambers of a Foraminifera.

*Keel.* A flange around the periphery of the test.

*Keriotheca.* A moderately thick transparent alveolar layer characteristic of the wall of the highly evolved Fusulinidae, in *Triticites* and *Schwagerina.*

*Lateral slope.* The straight, concave, or convex sloping part of the profile of a fusiform fusuline between the center and the pole.

*Lip.* A flange over the upper edge of the aperture, as in *Endothyra.*

*Lobulate.* Composed of a series of partial lobes, due to the inflation of the individual chambers or the deep depression of the sutures, as in *Ozawainella.*

*Median section.* A thin section of a Foraminifera cut perpendicularly to an axial section, which includes the proloculus; also called a sagittal section.

*Monothalamous.* Having a single chamber; often referred to as unilocular.

*Neanic.* Pertaining to a specimen in the young or adolescent stage of development in its life history.

*Nepionic.* Pertaining to a specimen in the epembryonic or babyhood stage of development in its life history.

*Nucleoconch.* The proloculus and first few chambers of the Foraminifera; the same as the juvenarium; refers particularly to the orbitoids.

*Ontogeny.* The developmental history of an organism; the series of changes in an organism during its entire life.

*Penultimate whorl.* Next to the outer whorl.

*Periphery.* The edge as seen in side view.

*Phyloephebic.* Pertaining to a racially mature form, characterized by a normality of the generic or specific traits, as *Fusulina.*

*Phylogeny.* The developmental history of a race of organisms in geologic time.

*Phylogerontic.* Pertaining to a senile race, characterized by a great complexity of structures and ornamentation or by loss of chambers. Phylogerontic forms tend to become bizarre, and all are end products of evolution, as *Bradyina.*

*Phyloneanic.* Pertaining to a racially young species, characterized by simple nonspecialized structures and lack of ornamentation. Phyloneanic genera or species are ancestral to more specialized related species, as *Eoschubertella.*

*Phylonepionic.* Pertaining to racially young or embryonic species which represent the first appearance of a new group of organisms, as *Endothyra.*

*Plane of coiling.* A plane perpendicular to the axis of coiling, which would longitudinally bisect coiled organisms.

*Planispiral.* Coiled with all whorls in the same plane.

*Pole.* The axial tip of the test of the fusoid Fusulinidae.

*Porcellaneous.* With an opaque, pearly, or porcelainlike luster; refers to Foraminifera with a calcareous imperforate test.

*Primary wall.* The tectum and diaphanotheca; also called protheca.

*Proloculus*, pl. *proloculi.* The initial chamber in all Foraminifera; sometimes incorrectly called proloculum.

*Protheca.* The fundamental wall of the Endothyridae and the primitive Fusulinidae and many other Paleozoic genera, consisting of a thin, dark outer layer, the tectum, and of a thicker, lighter-colored inner layer, the diaphanotheca. The primary wall.

*Provincial.* Applied to a fauna composed of species of restricted geographic range. The specimens of such a fauna are commonly bizarre; therefore, this fauna is easily distinguished from other contemporaneous faunas.

*Pseudobiserial.* A biserial appearance of forms with an elliptical periphery, produced by the involution of the coil on one side, as in the endothyroid stage of *Endothyranella pugnoidea.*

*Sagittal section.* A median section, which is transverse to the axis and through the proloculus.

*Secondary deposit.* Calcareous material deposited in chamber spaces by the organism after the construction of the primary wall structures, as in *Wedekindellina.*

*Septal furrows.* Depressions on the surface of the test of the Fusulinidae, marking the juncture between chambers.

*Septum*, pl. *septa.* A wall or partition separating the chambers.

*Sinistral.* Coiling in a counterclockwise manner, or left handed.

*Spirotheca.* The outer or upper wall of the test of the Fusulinidae.

*Subnautiloid.* Applied to organisms which are nearly planispiral but slightly asymmetrical and which have a broad back, or which are nautiloid in the adult stage and asymmetrically coiled in the young stage, as in *Pseudostaffella.*

*Suture.* A line on the surface of the test marking the juncture between chambers and between whorls.

*Tectorium*, pl. *tectoria.* Secondary wall material deposited above and below the primary wall of the Fusulinidae.

*Tectum*, pl. *tecta.* A thin, dense, porous, calcareous outer layer found in the wall of most Paleozoic Foraminifera; it overlies the diaphanotheca and the keriotheca.

*Test.* The skeleton or hard parts of a Foraminifera.

*Trochoid.* Top-shaped, as in *Tetrataxis.*

*Tunnel.* A narrow trough which provides a path of communication between the individual chambers, usually in the median area of the Fusulinidae; it is bounded by the chomata and produced by the resorption of a small part of the septa.

*Tunnel angle.* The angle formed between two lines projected from the center of the proloculus through the tangent of the inner edge of the chomata.

*Umbilicus.* A depression in the axial region of the test.

*Unilocular.* Refers to single-chamber Foraminifera; synonymous with monothalamous.

*Valve.* A calcareous plate extending into the vestibule over each aperture in the genera *Polytaxis* and *Tetrataxis.*

*Vestibule.* The concave ventral part of the test into which the apertures open, in the genera *Tetrataxis* and *Polytaxis*.

*Wall.* The enclosing structure of a chamber of a foraminiferal test.

# INDEX

[Italic numbers indicate descriptions]

Page

A

Acceleration, definition of ............... 58
Acknowledgments ......................... 9
Agglutinated, definition of ............... 58
Alveolar, definition of ................... 58
*Ammobaculites powersi* ................. 31
    *stormi* ............................. 33
*Amphiscites* ............................ 10
*angulata, Fusulinella* .................. 42
*angulata, Ozawainella* .................. 42
Antetheca, definition of ................. 58
*anthracosia, Spirorbis* .................. 9
Aperture, definition of .................. 58
Appression, definition of ................ 58
*atokaensis, Pseudostaffella*....13, 14, *43*, pl. 4
*atokensis, Staffella* ..................... 43
Axial filling, definition of ............... 58
Axial section, definition of .............. 58
Axis, definition of ....................... 58

B

Back, definition of ....................... 58
*baileyi, Endothyra* .................21, 24, 25
*Bairdia* ................................ 10
Bibliography ......................... 54-57
*biconvexa, Tetrataxis* .........14, 35, *38*, pl. 3
*biserialis, Globivalvulina*.......13, 14, 21, 35, *36*, pl. 3
*biumbonata, Ozawainella* ................. 43
*bowmani, Endothyra*............7, 23-24, pl. 1
Brady, H. B. ..............24, 25, 27, 41, 43
*Bradyina*............10, 11, 18, 20, 21, 22, 31, *34*, 37, 58-59
    *holdenvillensis* ...................... 35
    *magna* ..............13, 14, *34*, pls. 2, 3
    *nautiliformis* ....................34, 35
Brown, Thomas, quoted ................. 23
*bulbosa, Earlandia* ........13, 14, 18, *41*, pl. 4
*bulbosa, Hyperammina* ................... 41
*bulloides, Globivalvulina* ................ 36
*bulloides, Valvulina* .................... 36

C

Cementing specimens .................... 15
Choma, definition of .................... 58
*ciscoensis, Orobias* ..................... 42
*ciscoensis, Ozawainella*........13, 14, *42*, pl. 4
*ciscoensis, Staffella* .................... 42
*Climacammina* .......................... 10
*Codonofusiella* .......................... 21
*Composita* ............................. 9
*concava, Tetrataxis*..13, 14, 35, *37*, 38, 39, pl. 3
*conica, Tetrataxis* ...................... 37
*Conodonts* ............................. 10
Corals ...........................9, 10, 11
*Cornuspira Schlumbergi* ................. 22
*corona, Tetrataxis*........13, 14, 36, *39*, pl. 3
Cosmopolitan, definition of .............. 58
*Cribrospira* ......................19, 20, 21
*Cribrostomum* .......................... 10
Crinoid columnals ........................ 9
Cushman, J. A., quoted ................. 17
*cylindrica, Fusulina* ....................7, 47

D

*decora, Profusulinella* ................... 47
*depressa, Tetrataxis maxima* ............. 38
Dextral, definition of .................... 58
Diaphanotheca, definition of ............. 58
*dunbari, Wedekindellina* ................. 50
Dwarfed fauna, definition of ............. 58

E

*Earlandia* ............................22, *41*
    *bulbosa* ..............13, 14, 18, *41*, pl. 4
    *perparva* ............................ 41
*elongata, Hyperammina* .................. 41
*Endothyra*....7, 10, 11, 18, 19-22, *23*, 31-33, 35, 37, 39, 41, 58-59, pls. 1, 2
    *baileyi* .......................21, 24, 25
    *bowmani* ................7, 23-24, pl. 1
    *excentralis* ........................... 28
    *kennethi* ...............14, 27, *28*, pl. 1
    key to species of ..................... 27
    *media* ............13, 14, 27, *30*, 33, pl. 1
    *ovata* ...........................29, 30
    *teres* ..................14, 27, *29*, pl. 1
    *tortilis* ..............14, *27*, 28, 29, pl. 1
    *whitesidei* ........13, 14, 27, *30*, pls. 1, 2
*Endothyranella*......7, 10, 18, 20, 21, 22, *31*, 37, 39, 58
    *minuta* .......................32, 33, 34
    *powersi* ............................. 31
    *pugnoidea*........14, *32*, 33, 34, 60, pl. 2
    *stormi* ...............13, 14, 18, *33*, pl. 2
Endothyridae ..................10, 23-40, 60
Endothyrinae ......................... 23-35
Endothyroid, definition of ............... 58
    juvenarium, definition of ........... 58
    stage, definition of ................. 58
*Eoschubertella* ..........19, 20, *44*, 46, 47, 59
    *lata* ................................. 44
    *mexicana* .........13, 14, *45*, 47, pls. 4, 5
Ephebic, definition of ................... 58
*euryteines, Fusulina* ..................48, 49
*euthusepta, Fusulinella* .................. 50
*euthysepta, Wedekindellina*....13, 14, *50*, pl. 5
Evolute, definition of ................... 58
Evolution, definition of ................. 58
*excentralis, Endothyra* .................. 28

Page

F

Fibrous, definition of .................. 58
*fittsi, Fusulinella* ........................ 46
*fittsi, Profusulinella* .........14, 45, *46*, pl. 5
Fluting, definition of .................. 58
Foramen, definition of .................. 58
Form ratio, definition of ............... 58
Fusiform, definition of ................. 59
Fusoid, definition of .................... 59
*Fusulina* ..................10, 20, 45, *47*, 59
*cylindrica* ........................7, 47
*euryteines* ........................48, 49
*girtyi* ................................ 48
*haworthi* ...............13, 14, *48*, pl. 5
*kayi* ................................... 49
*leei* ................................... 49
*lucasensis* ............................ 49
*novamexicana* ..........13, 14, *48*, pl. 5
*pumila* ................................ 49
*stookeyi* .............................. 49
*Fusulinella* ............................ 20
*angulata* .............................. 42
*euthusepta* ............................ 50
*fittsi* ................................. 46
*haworthi* .............................. 49
*minuta* ................................ 50
(*Girtyina*) *ventricosa* ............... 48
Fusulinidae....7, 8, 10, 11, 17, 18, 19, 21, 22, 35, 42-53, 58-60
Fusulininae ......................24, 47-53

G

*gallowayi, Nanicella* ..................21, 25
Gerontic, definition of .................. 59
*girtyi, Fusulina* ........................ 48
*Girtyina* ................................ 47
*haworthi* ............................... 48
(*Girtyina*) *ventricosa, Fusulinella* ........ 48
*Globivalvulina* .......10, 11, 18, 20, 21, *36*, 58
*biserialis* .........13, 14, 21, 35, *36*, pl. 3
*bulloides* .............................. 36
*ovata* .................................. 36
Glomospiral, definition of ............... 59
*Glyphostomella* ......................... 34
*gracilis, Hyperammina* .................. 41
*gracilis rugosa, Hyperammina* ........... 41

H

*haworthi, Fusulina* ..........13, 14, *48*, pl. 5
*haworthi, Fusulinella* .................. 49
*haworthi, Girtyina* ..................... 48
*Hemigordius* ............................ *22*
*liratus* ..............13, 14, 18, *22*, pl. 1
*schlumbergeri* .......................... 22
*holdenvillensis, Bradyina* .............. 35
*hollingsworthi, Pseudostaffella* ......... 44
*Hustedia* ................................ 9
Hyaline, definition of ................... 59
*Hyperammina* ............................ 41
*bulbosa* ................................ 41
*elongata* ............................... 41

Page

*gracilis* ............................... 41
*gracilis rugosa* ........................ 41

I

International Commission on Zoological Nomenclature, rules of .............24, 25
Article 21, quoted ................. 24
Involute, definition of .................. 59
Isomorph, definition of .................. 59

J

Juvenarium, definition of ................ 59

K

*kayi, Fusulina* ......................... 49
Keel, definition of ...................... 59
*kennethi, Endothyra* .........14, 27, *28*, pl. 1
Keriotheca, definition of ................ 59
*keytei maccoyensis, Pseudostaffella* ....... 44

L

*labiata, Tetrataxis* ..........14, 36, *38*, pl. 3
*laheei, Polytaxis*....13, 14, 36, 39, *40*, pls. 3, 4
*lata, Eoschubertella* .................... 44
*lata, Schubertella* ...................... 44
*lata, Tetrataxis* ........................ 39
Lateral slope, definition of ............. 59
*leei, Fusulina* .......................... 49
Lip, definition of ....................... 59
*liratus Hemigordius* .......13, 14, 18, *22*, pl. 1
Lobulate, definition of .................. 59
*lucasensis, Fusulina* .................... 49

M

*maccoyensis, Pseudostaffella keytei*........ 44
*magna, Bradyina* ..........13, 14, *34*, pls. 2, 3
*Marginifera* ............................. 9
*maxima, Tetrataxis* ..................... 38
*maxima depressa, Tetrataxis* ............ 38
*media, Endothyra*......13, 14, 27, *30*, 33, pl. 1
Median section, definition of ............ 59
Megafossils ............................... 8
*mexicana, Eoschubertella*.......13, 14, *45*, 47, pls. 4, 5
*Millerella* ....11, 19, 20, 21, 22, 24, 25, 26, 42
*minuta, Endothyranella* ...........32, 33, 34
*minuta, Fusulinella* ..................... 50
*minuta, Wedekindellina* ........50, 51, 52, 53
Monothalamous, definition of ............. 59
Moore, R. C., Lalicker, C. G., and Fischer, A. G., quoted ....................... 17
*munda, Profusulinella* .................. 47

N

*nalivkini, Paraendothyra* ................ 27
*Nanicella* .................19, 20, 21, 22, 26
*gallowayi* ........................21, 25
*Naticopsis* .............................. 10
*nautiliformis, Bradyina* ..............34, 35

Page

Neanic, definition of .................... 59
*needhami, Pseudostaffella* .............43, 44
Nepionic, definition of .................. 59
*Nipponitella* ........................... 21
Nodosinellidae ........................... 41
*novamexicana, Fusulina* ......13, 14, *48*, pl. 5
Nucleoconch, definition of ............... 59

O

*oliviformis, Profusulinella* ............... 47
Ontogeny, definition of .................. 59
*Orobias* ................................. 42
  *ciscoensis* ............................ 42
*ovata, Endothyra* ......................29, 30
*ovata, Globivalvulina* .................... 36
*Ozawaina* ............................... 42
*Ozawainella* ..................10, 20, *42*, 59
  *angulata* .............................. 42
  *biumbonata* ............................ 43
  *ciscoensis* ..............13, 14, *42*, pl. 4
  *radiata* ............................... 43
Ozawainellinae ...................19, 42-43

P

*Paraendothyra* .........................26, 27
  *nalivkini* ............................. 27
*pararhomboidea, Profusulinella* ........... 46
Penultimate whorl, definition of .......... 59
Periphery, definition of .................. 59
*perparva, Earlandia* ..................... 41
Phillips, John, quoted .................... 24
*Phillipsia* ............................... 10
Phyloephebic, definition of ............... 59
Phylogeny, definition of .................. 59
  Staunton genera ....................19-22
Phylogerontic, definition of .............. 59
Phyloneanic, definition of ................ 59
Phylonepionic, definition of .............. 59
Plane of coiling, definition of ........... 59
Planispiral, definition of ................ 59
*Plectogyra* .................7, 23, 25, 26, 27
  *plectogyra* ............................ 25
Pole, definition of ....................... 59
*Polytaxis*....10, 20, 21, 22, 37, 38, *39*, 60, 61
  *laheei*..........13, 14, 36, 39, *40*, pls. 3, 4
Porcellaneous, definition of .............. 60
*powersi, Ammobaculites* ................... 31
*powersi, Endothyranella* .................. 31
Primary wall, definition of ............... 60
*Prismopora* ............................... 9
*Profusulinella*...........20, 24, 25, 45, *46*, 58
  *decora* ................................ 47
  *fittsi* ..................14, 45, *46*, pl. 5
  *munda* ................................. 47
  *oliviformis* ........................... 47
  *pararhomboidea* ........................ 46
Proloculus, definition of ................. 60
Protheca, definition of ................... 60
Provincial, definition of ................. 60
Pseudobiserial, definition of ............. 60

Page

*Pseudostaffella* ..........10, 11, 20, 42, *43*, 60
  *atokaensis* ..............13, 14, *43*, pl. 4
  *hollingsworthi* ........................ 44
  *keytei maccoyensis* .................... 44
  *needhami* ............................43, 44
*pugnoidea, Endothyranella*......14, *32*, 33, 34, 60, pl. 2
*pumila, Fusulina* ........................ 49

R

*radiata, Ozawainella* ..................... 43
*Rhombopora* ............................... 9
*rugosa, Hyperammina gracilis* ............ 41

S

Sagittal section, definition of ........... 60
*Schellwienia* ............................ 47
*schlumbergeri, Hemigordius* .............. 22
*Schlumbergi, Cornuspira* .................. 22
*Schubertella* .........................45, 46
  *lata* .................................. 44
Schubertellinae ................19, 24, 43-47
*Schwagerina* ............................. 59
Secondary deposit, definition of ......... 60
Septal furrows, definition of ............ 60
Septum, definition of ..................... 60
Sinistral, definition of .................. 60
Spirillinidae ............................. 22
Spirillininae ............................. 22
*Spirorbis* ............................... 10
  *anthracosia* ............................ 9
Spirotheca, definition of ................. 60
*Staffella* ........................42, 43, 44
  *atokensis* ............................. 43
  *ciscoensis* ............................ 42
Staunton fauna, abundance of species of.. 14
  biologic environment of ............... 11
  correlation with other middle Pennsylvanian Foraminifera ..............13-14
  cosmopolitan nature of ................ 11
  diversity of .......................10-11
  dwarfed ............................... 10
  geographic range of ...........11, 13, 14
  geologic range of .................13, 14
  location of ........................... 8-9
  phylogeny of .......................19-22
  physical environment of ............... 11
  specialization of ..................... 11
  species of ............................ 14
Staunton formation ......8, 11, 13, 19, 51, 52
Stonefort formation ..................51, 52
*stookeyi, Fusulina* ...................... 49
*stormi, Ammobaculites* ................... 33
*stormi, Endothyranella*....13, 14, 18, *33*, pl. 2
Subnautiloid, definition of ............... 60
Suture, definition of ..................... 60

T

Tectorium, definition of .................. 60
Tectum, definition of ..................... 60
*teres, Endothyra* .............14, 27, *29*, pl. 1

Page

Test, definition of ..................... 60
Tetrataxinae ......................... 35-40
*Tetrataxis*........10, 11, 20, 21, *37*, 40, 60, 61
*biconvexa* ..............14, 35, *38*, pl. 3
*concava* ......13, 14, 35, *37*, 38, 39, pl. 3
*conica* ........................... 37
*corona* ..............13, 14, 36, *39*, pl. 3
*labiata* ................14, 36, *38*, pl. 3
*lata* ............................. 39
*maxima* ........................... 38
*maxima depressa* .................. 38
Thin sections ......................7, 15-17
Thompson, M. L., quoted ............... 45
*tortilis, Endothyra* ........14, *27*, 28, 29, pl. 1
*Triticites* ...........................58, 59
Trochoid, definition of ................ 60
Tunnel, definition of .................. 60
Tunnel angle, definition of ............. 60

U

Umbilicus, definition of ................ 60
Unilocular, definition of ............... 60

Page

V

Valve, definition of .................... 60
*Valvulina* ............................ 37
*bulloides* .......................... 36
*ventricosa, Fusulinella (Girtyina)* ........ 48
Vestibule, definition of ................ 61

W

Wall, definition of ..................... 61
Wall structure ......................7, 17-19
*Wedekindella* ......................... 50
*Wedekindellina* .............10, 20, *50*, 58, 60
*dunbari* ........................... 50
*euthysepta* ..............13, 14, *50*, pl. 5
*minuta* ...................50, 51, 52, 53
*Wedekindia* ........................... 50
*whitesidei, Endothyra*...13, 14, 27, *30*, pls. 1, 2

Z

Zeller, E. J., quoted .................. 25

## PLATES 1-5

**All figured specimens are catalogued and deposited in the Paleontologic Collections of Indiana University.**

# PLATE 1

Figures 1. *Hemigordius liratus* Cushman and Waters. X60. (p. 22).

a. Side view as seen when covered with a film of water. The glomospiral coil is indistinct as seen from the dry specimen.

b. Edge view; the keel and part of the test below the aperture have been crushed. Plesiotype no. 5314.

2, 3. *Endothyra bowmani* Phillips. (p. 23).

2. X55. Brown's figure of *Endothyra bowmani* Phillips. Note 19 chambers in the outer whorl, the variation in angle and distances apart of the septa, and the asymmetrical juvenarium, indicating a fusuline like *Schubertella, Eoschubertella, Profusulinella,* or *Millerella.* Compare also with the median sections of any of the Fusulinidae on plates 4 and 5.

3. The type figure of *Endothyra* Phillips reproduced at the original size of publication. Note the number of chambers in the outer whorl, eight, and the asymmetry of the juvenarium.

4, 5. *Endothyra tortilis* n. sp. (p. 27).

4. X55. Side and apertural views. Holotype no. 5306A.

5. X95. Partly restored and retouched photograph of the median section. Note the transverse fibers in the outer wall of the fourth and fifth chambers from the end. Paratype no. 5306B.

6-8. *Endothyra kennethi* n. sp. (p. 28).

6. X40. Side and apertural views of a well-preserved specimen. Holotype no. 5303A.

7. X55. A median section with the last chamber restored. Note the fibers in the thinner parts of the section. Paratype no. 5303B.

8. X55. Side and apertural views of a specimen partly distorted by crushing. Compare with *E. tortilis,* whose outer whorl is more asymmetrical as seen in the apertural view (figs. 4 and 5 above). Paratype no. 5303C.

9, 10. *Endothyra teres* n. sp. (p. 29).

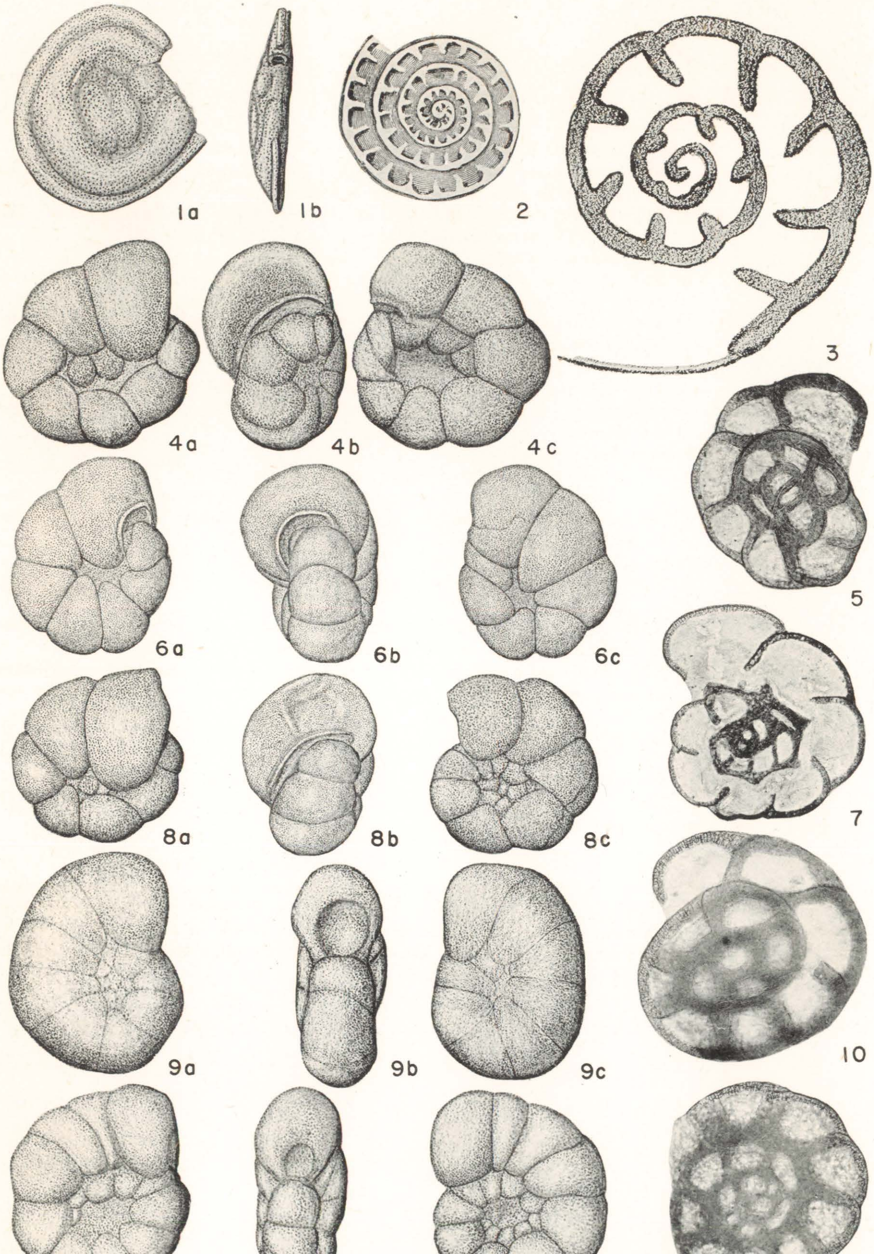
9. X80. Side and apertural views. Note especially the nondepressed sutures and the high arched aperture. Holotype no. 5305A.

10. X90. A retouched photograph of a median section. Paratype no. 5305B.

11, 12. *Endothyra media* Waters. (p. 30).

11. X75. Side and apertural views. This may be the young of *E. whitesidei.* (Compare with plate 2, figure 1.) Plesiotype no. 5304A.

12. X130. A retouched photograph of a median section. Note how recrystallization has given a granular appearance to the wall. The general fibrous texture is preserved in part, however, as is shown in the outer wall of the third chamber. Also note the dark tectumlike outer layer in the same part of the photograph. Plesiotype no. 5304B.




HEMIGORDIUS AND ENDOTHYRA

# PLATE 2

Figures 1, 2. *Endothyra whitesidei* Galloway and Ryniker. (p. 30).

1. X40. Side and apertural views. Plesiotype no. 5307A.

2a. X55. Retouched photograph of median section. Note how the plane of coiling twists through 90°; externally, however, this species appears to be nearly planispiral.

2b. X165. Part of the median section enlarged. This figure shows the second, third, and fourth chambers of the outer whorl of the preceding figure. Note the thin, dark tectum, which is most noticeable where the wall of one chamber is joined to the wall of the preceding chamber in the outer whorl. The transversely fibrous diaphanothecalike structure also may be seen. The photograph has not been retouched. Plesiotype no. 5307B.

3-5. *Endothyranella pugnoidea* n. sp. (p. 32).

3. X80. Side and apertural views. The endothyroid young stage of this specimen is compressed in a horizontal direction. Holotype no. 5308A.

4. X115. Side and apertural views. This shows the compression of the young part in vertical direction that gives the endothyroid stage a pseudobiserial appearance on one side. Paratype no. 5308B.

5. X95. Median section. Note how the juvenarium is coiled at about 90° to the plane of the last whorl of the young stage, just as in *Endothyra*. The thickening around the aperture of the uniserial part is present in both species illustrated of the genus. Note also the granularity of the wall and the suggestion of transverse fibers. The transverse fibers are more distinct in the thin section than they are in the photograph, which has been retouched. Paratype no. 5308C.

6, 7. *Endothyranella stormi* (Cushman and Waters). (p. 33).

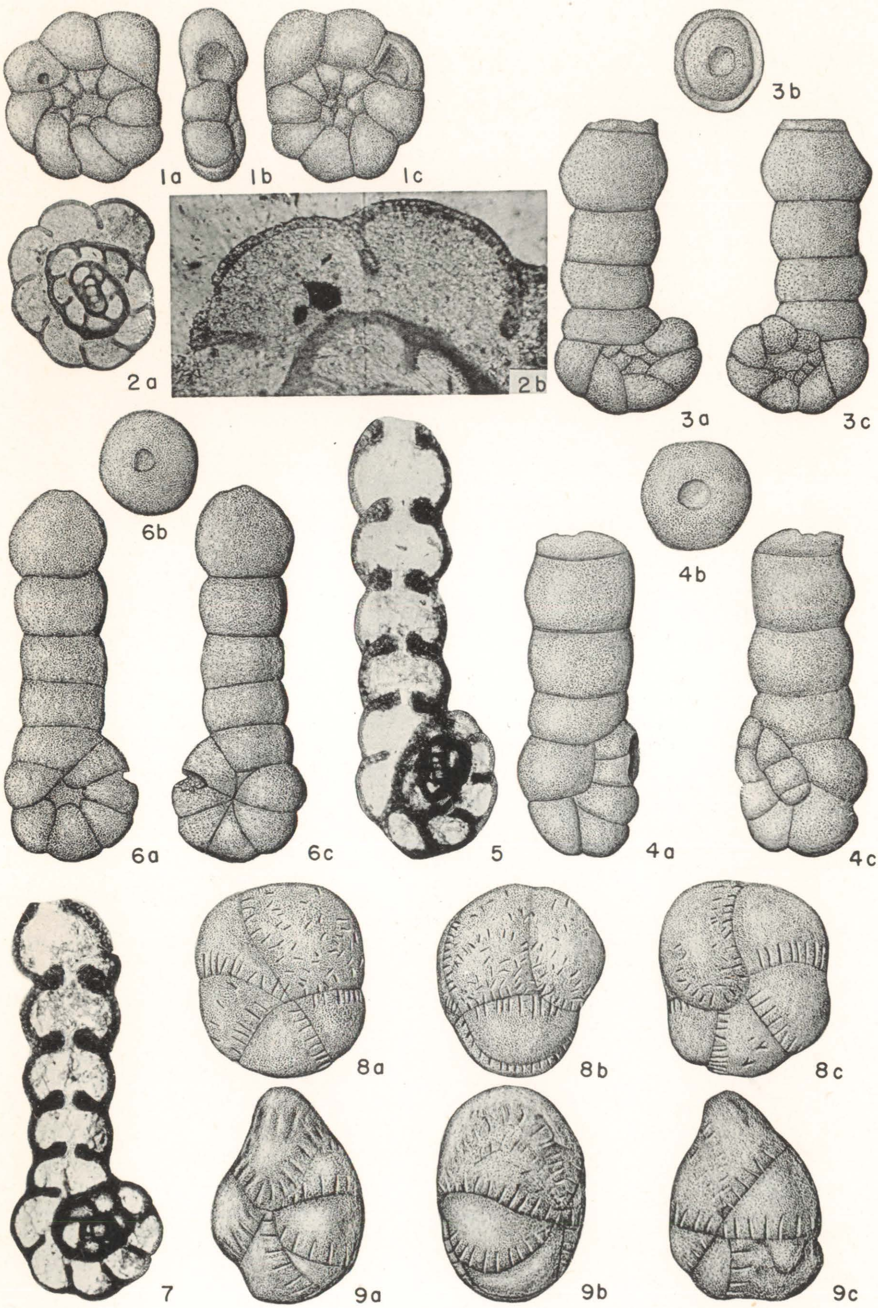
6. X75. Side and apertural views. The young stage is circular in outline, as compared with the elliptical periphery of the endothyroid stage of the preceding *E. pugnoidea*. Plesiotype no. 5309A.

7. X90. Retouched photograph of median section. The juvenarium is coiled in a plane 90° to the plane of the adult whorl. The species also shows the thickening around the opening of each chamber of the uniserial stage. The septa of the last 4 or 5 chambers of the coiled part indicate that the endothyroid stage probably had an aperture as a narrow slit at the base of the septal face. Plesiotype no. 5309B.

8, 9. *Bradyina magna* Roth and Skinner. (p. 34).

8. X10. Side and apertural views of a well-preserved, undeformed specimen. The last chamber is added to one side of the penultimate chamber in the specimen. In some specimens the last whorl is nautiloid. Plesiotype no. 5301A.

9. X15. Side and apertural views of a badly distorted specimen. Most of the specimens have been crushed or distorted in various ways. Plesiotype no. 5301B.




ENDOTHYRA, ENDOTHYRANELLA, AND BRADYINA

# PLATE 3

Figures 1, 2. *Bradyina magna* Roth and Skinner. (p. 34).

1a. X15. An unretouched photograph of an axial section; part of the structure is obscured by infiltrated material.

1b. X15. A retouched and partly restored photograph of the same showing the manner of coiling. Plesiotype no. 5301C.

2. X20. A partly retouched median section showing the manner of coiling. Notice the obviously coarse, alveolar wall structure. Plesiotype no. 5301D.

3-5. *Globivalvulina biserialis* Cushman and Waters. (p. 36).

3. X55. Back, side, and apertural views. Plesiotype no. 5313A.

4. X60. A longitudinal or vertical section which is slightly off center. Notice the coarse, alveolar wall structure. Plesiotype no. 5313B.

5. X65. A section transverse to the longitudinal section which gives some indication of the manner of coiling. Plesiotype no. 5313C.

6, 7. *Tetrataxis concava* Galloway and Ryniker. (p. 37).

6. X40. Dorsal, side, and ventral views. Plesiotype no. 5320A.

7. X55. An unretouched photograph of a cross section. Plesiotype no. 5320B.

8, 9. *Tetrataxis biconvexa* n. sp. (p. 38).

8. X15. Dorsal, side, and ventral views. The test is large, and the chambers are narrow dorsally. The radial projections on the ventral side are long. Holotype no. 5319A.

9. X40. An unretouched photograph of a cross section. The alveolar structure can be seen in the interior of the young part of the test; all exterior parts are granular because of recrystallization. The juvenarium was lost in the grinding of the section. Paratype no. 5319B.

10, 11. *Tetrataxis labiata* n. sp. (p. 38).

10. X35. Dorsal, side, and ventral views. The ventral view shows the lips on the radial projections which characterize the species. The periphery also is characteristically lobulate. Holotype no. 5322A.

11. X55. A cross section. The granularity of the wall is due to recrystallization. This is an unretouched photograph. Paratype no. 5322B.

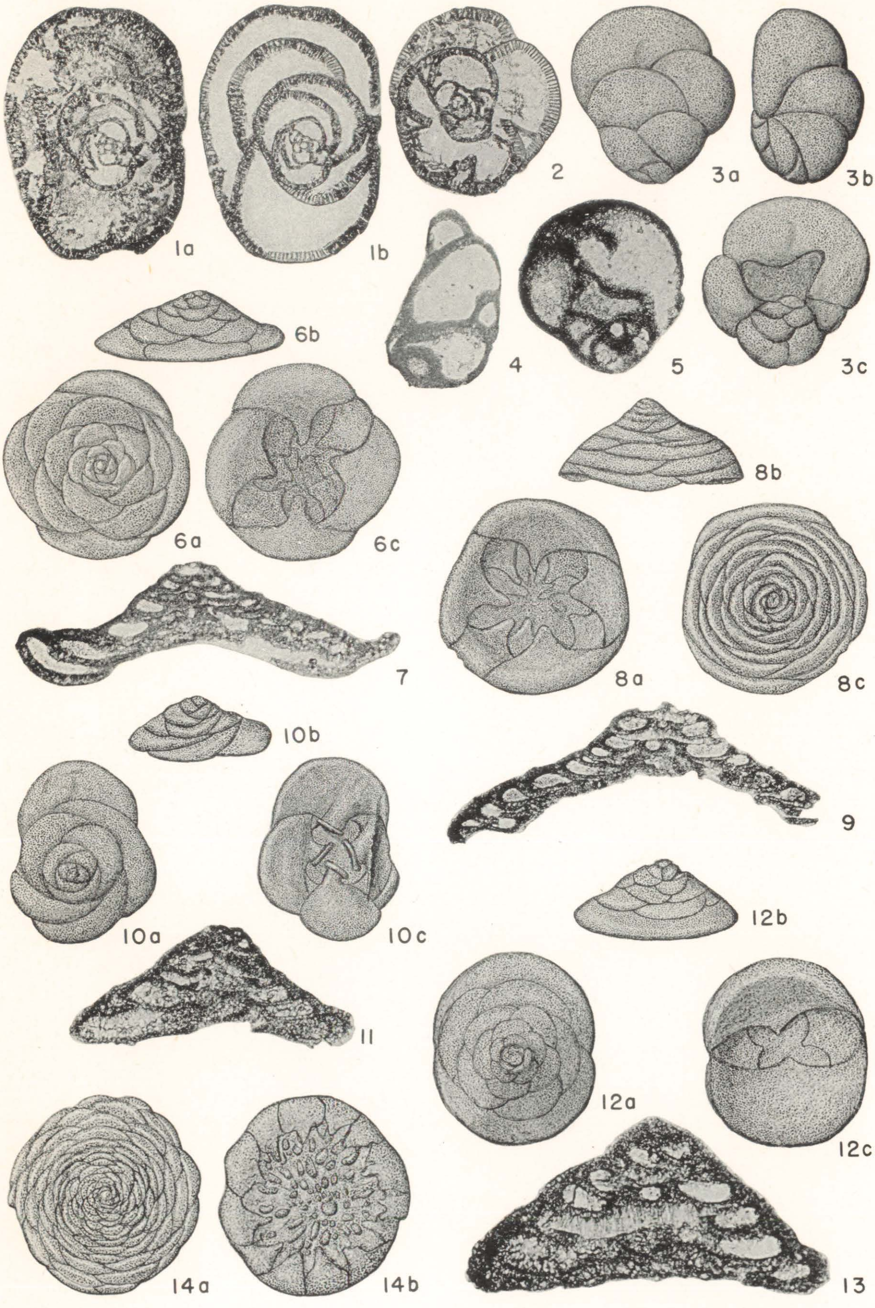
12, 13. *Tetrataxis corona* Cushman and Waters. (p. 39).

12. X50. Dorsal, side, and ventral views. There are only two chambers in the outer whorl. Plesiotype no. 5321A.

13. X95. An unretouched photograph of a cross section. The coarse, alveolar structure is prominent in the center of the test. Plesiotype no. 5321B.

14. *Polytaxis laheei* Cushman and Waters. (p. 40).

X10. Dorsal and ventral views. The chambers are short and numerous in the outer whorl. The papillose ventral surface is due to the radial projections of chambers of the inner whorls. Plesiotype no. 5316A.




BRADYINA, GLOBIVALVULINA, TETRATAXIS, AND POLYTAXIS

# PLATE 4

Figures 1, 2. *Polytaxis laheei* Cushman and Waters. (p. 40).

1. X20. A cross section that shows both fibrous and recrystallized features in the wall. Plesiotype no. 5316B.
2. X20. A section transverse to the cross section shows the granular appearance of the outer part of the wall, beneath which is a finely fibrous layer that cannot be distinguished on the photograph. Plesiotype no. 5316C. Both of the photographs are unretouched.

3. *Earlandia bulbosa* (Cushman and Waters). (p. 41).

3a, b. X60. Side and end views. The tubular part has been crushed and broken.

3c. X60. A longitudinal section of the same specimen. The various partitions are due to parts of the wall which have been pushed inward and are not true partitions. The wall in the specimen is completely recrystallized and is not composed of arenaceous or foreign material. The photograph has not been retouched. Plesiotype no. 5302.

4-8. *Ozawainella ciscoensis* (Harlton). (p. 42).

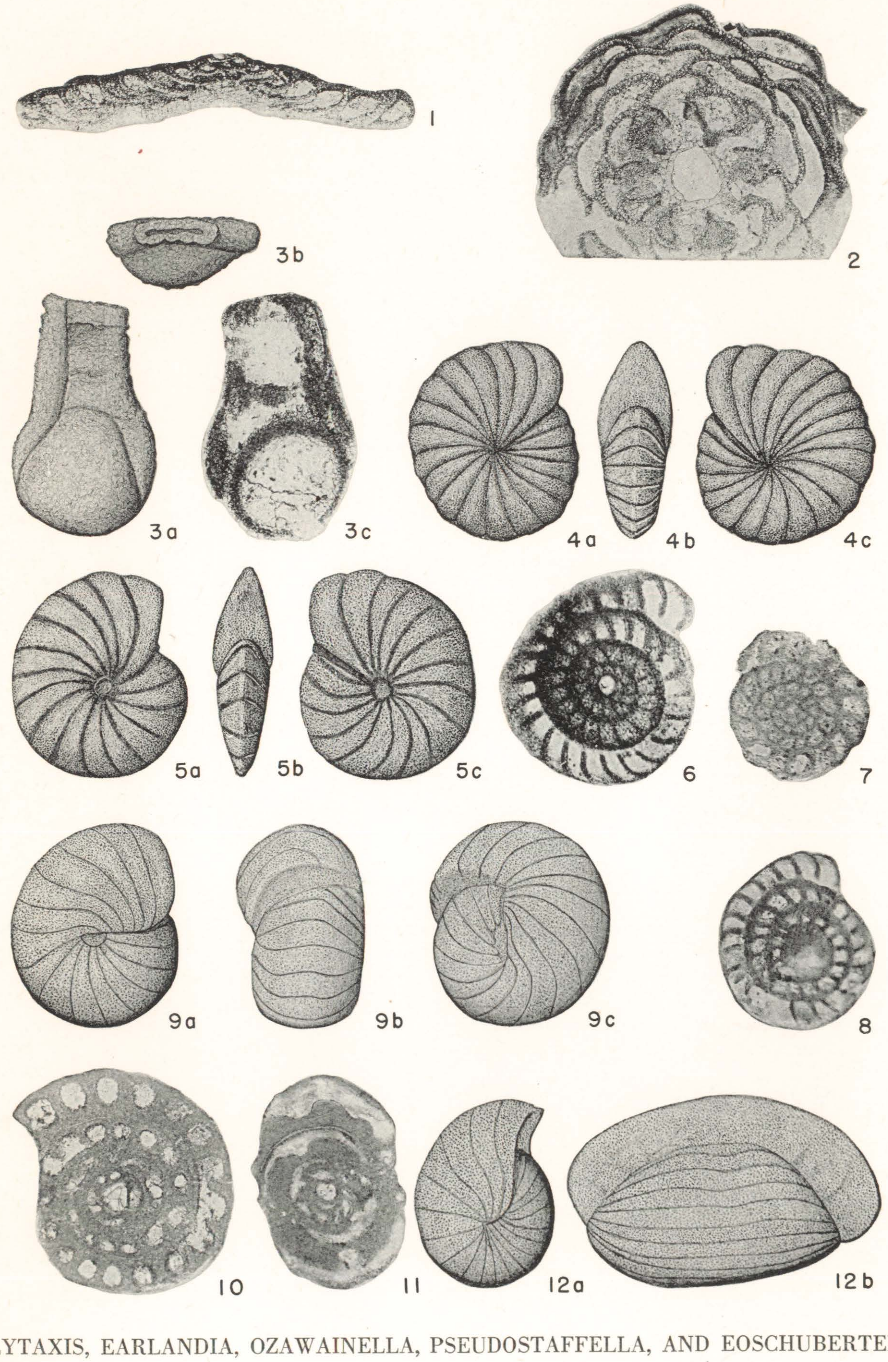
4. X80. Side and edge views of a specimen which has a completely embracing outer whorl. Plesiotype no. 5315A.
5. X80. Side and edge views of a specimen in which the outer whorl is not completely embracing; thus a small umbilicus is present. In addition, the sutures appear limbate owing to weathering of part of the outer test wall. Plesiotype no. 5315B.
6. X75. A cross section in which the outer test wall is highly recrystallized. Plesiotype no. 5315C.
7. X65. A cross section of a completely recrystallized test. Plesiotype no. 5315D.
8. X75. A cross section, a little off center, in which the test is well preserved. Plesiotype no. 5315E.

9-11. *Pseudostaffella atokaensis* (Thompson). (p. 43).

9. X65. Side and edge views showing the asymmetrical nature of the coil. Plesiotype no. 5318A.
10. X80. A median section. The dark area beneath the tectum is the transversely fibrous diaphanotheca, which scarcely can be made out from the photograph, but which can be seen in the thin section. Plesiotype no. 5318B.
11. X60. Axial section. The angle of the tunnel to the vertical also shows the nature of the coil. Plesiotype no. 5318C.

12. *Eoschubertella mexicana* Thompson. (p. 45).

X100. Side and antethecal views. Plesiotype no. 5310A.




POLYTAXIS, EARLANDIA, OZAWAINELLA, PSEUDOSTAFFELLA, AND EOSCHUBERTELLA

# PLATE 5

Figures 1-5. *Eoschubertella mexicana* Thompson. (p. 45).

1, 2, 3. X30. Three typical specimens which show the degree of variation in external characteristics. Plesiotype nos. 5310B, 5310C, and 5310D.

4. X85. Median section showing the large megaspheric proloculus. The dark layer beneath the tectum is the transversely fibrous diaphanotheca, not a lower tectorium. This is especially clear in the proloculus as seen through the microscope and may be detected faintly in the illustration. Plesiotype no. 5310E.

5. X145. An axial section also showing the large proloculus. Plesiotype no. 5310F.

6-9. *Profusulinella fittsi* (Thompson). (p. 46).

6, 7. X20. Antethecal and back views of two typical specimens. Plesiotype nos. 5317A and 5317B.

8. X65. Median section. The dark layer beneath the tectum is a transversely fibrous diaphanotheca rather than a lower tectorium. Plesiotype no. 5317C.

9. X75. Axial section. Plesiotype no. 5317D.

10-13. *Fusulina novamexicana* Needham. (p. 48).

10, 11. X6. Antethecal views of two specimens. Plesiotype nos. 5312A and 5312B.

12. X10. Median section. Plesiotype no. 5312C.

13. X10. Axial section. Plesiotype no. 5312D.

14-17. *Fusulina haworthi* (Beede). (p. 48).

14, 15. X6. Antethecal views of two specimens. Plesiotype nos. 5311A and 5311B.

16. X15. Median section. Plesiotype no. 5311C.

17. X15. Axial section. Plesiotype no. 5311D.

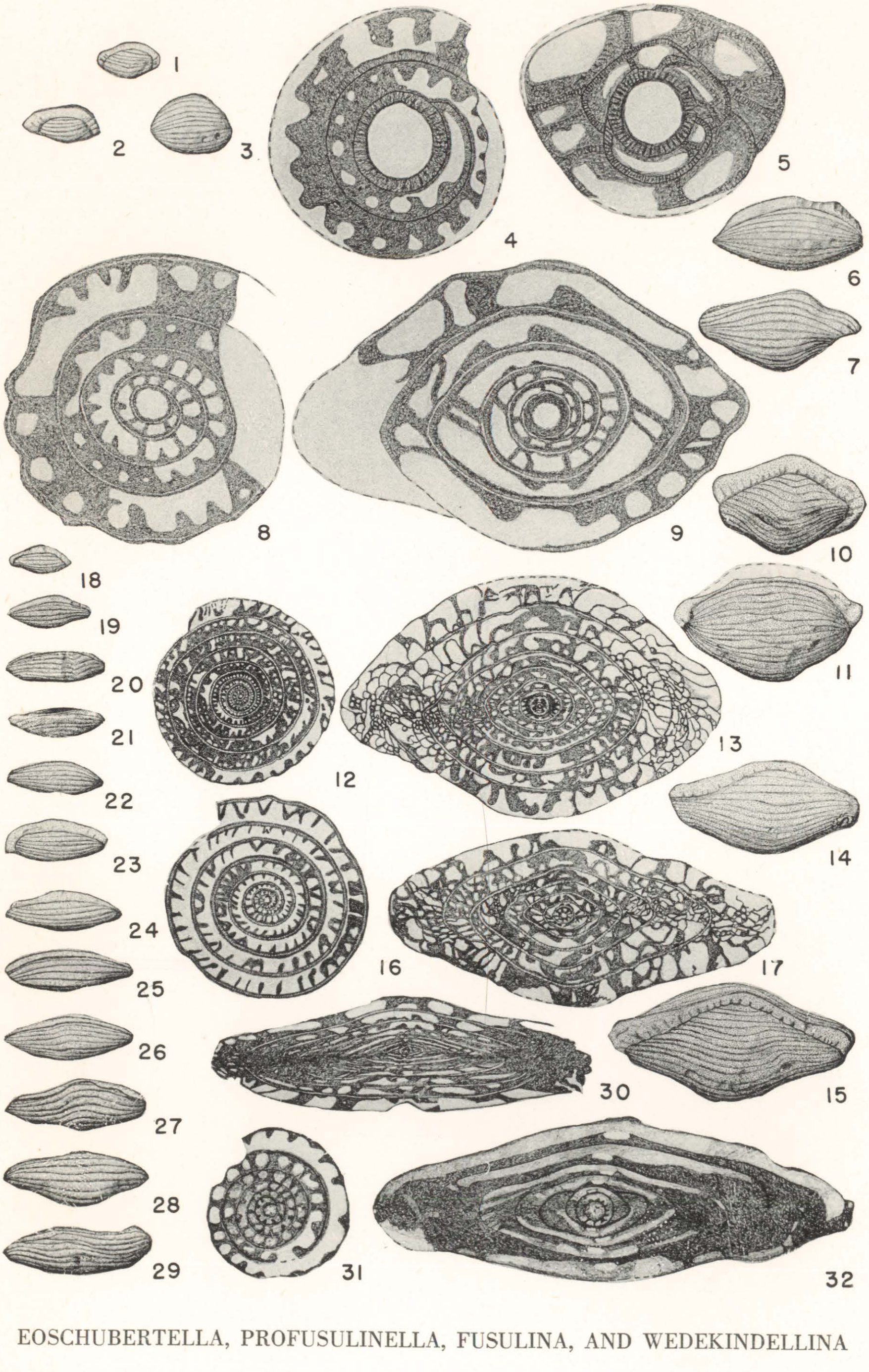
18-32. *Wedekindellina euthysepta* (Henbest). (p. 50).

18-29. X15. An ontogenetic series of young specimens. The largest is somewhat smaller than the adult specimen. Plesiotype nos. 5323A-5323L.

30. X15. Axial section of an adult specimen. Plesiotype no. 5323M.

31. X45. Median section of a young specimen. Plesiotype no. 5323P.

32. X45. Axial section of a young specimen. This specimen is only about one-third the size of the preceding adult form. Plesiotype no. 5323N.




EOSCHUBERTELLA, PROFUSULINELLA, FUSULINA, AND WEDEKINDELLINA